FOR OFFICIAL USE ONLY

COMBAT AND FIELD MEDICINE PRACTICE

(Title IV of Military-Medicine Operations Courses)

PREPARED BY

BUREAU OF NAVAL PERSONNEL

NAVPERS 10819

FEBRUARY 1949

COMBAT AND FIELD MEDICINE PRACTICE

(Title IV of Military-Medicine Operations Courses)

PREPARED BY

U.S BUREAU OF NAVAL PERSONNEL

NAVPERS 10819

FEBRUARY 1949

PREFACE

This text was prepared primarily for use in the training of Naval Reserve officers of the Medical Department of the United States Navy. The title, *Combat and Field Medicine Practice,* is one of a series of military-medical operations courses which will be made available to Reserve officers through the correspondence course training program.

This book covers a wide range of subjects related to the work of officers of the Medical Department during amphibious operations and in other combat areas. Chapter one includes a brief discussion of amphibious operations and the general problems of the organization and operation of medical units during amphibious landings. The next two chapters present narrative accounts of amphibious operations in both the Pacific and Mediterranean areas during World War II. Some specific problems in handling battle casualties are covered in chapter four. The problems of field sanitation and the use of chemicals for insect control are discussed at length in chapters five and six. Finally, the overall problem of medical material logistics concludes the book. The objective of the text is to acquaint the officers of the Medical Department with the many problems and operational difficulties encountered in the application of their professional skill and knowledge under combat conditions.

This compilation of information and instructional material is the result of the joint efforts of the Bureau of Medicine and Surgery and the Naval Reserve Training Publications Project of the Bureau of Naval Personnel.

CONTENTS

CHAPTER 1

AMPHIBIOUS WARFARE

HISTORICAL BACKGROUND

One of the spectacular military developments of the last war was the demonstration that amphibious landings against a heavily defended beachhead could succeed despite every possible defense the enemy was able to muster. Landing operations of one type or another have been an accepted commonplace for centuries; however, prior to World War II military experts regarded a landing on a beach defended by modern artillery, pillboxes, and machine guns, which had come into use during the first World War, as an "impossibility."

The first amphibious landing of a modern type ever to be carried out on a large scale by United States Forces during combat was staged by the Marines at Guadalcanal in August, 1942. This assault was followed by a series of sea-borne operations that were to be a decisive factor, not only in the conquest of Europe but also in the islands of the Pacific.

Credit for the development of the highly complex technique of amphibious assault as it is known today should go to the Marine Corps, and more specifically to the Fleet Marine Force. It was the corps' forward-looking program of study, research, and practical field tests that provided this country with the doctrine, technique, and equipment which became the recognized pattern of amphibious warfare adopted not only by our Army and Navy but also by the armed forces of eight Allied nations as well.

A major step in the development of the technique of amphibious warfare came in 1921, when the Marine Corps established its plan, its forces, and its schools for the express purpose of reducing landing operations to a scientific and technical basis. In that year a school devoted to the study of amphibious operations was set up at Quantico, Va. Two expeditionary forces were organized to test landing methods in actual maneuvers with the Fleet, and, even more important, there was produced a basic war plan that foretold the step-by-step base seizure, in which amphibious attacks would play a deciding role in the Navy's westward march across the Pacific during World War II.

Over the ensuing years further advances were made in the improvement of technique, organization, and equipment. In 1933, the Fleet Marine Force, the unit of the Marines responsible for amphibious landings, was officially recognized for the first time. At the same time the Marine Corps Equipment Board, the first professional body in this country devoted to the development of amphibious landing materiel, was set up. Two years later the first field maneuvers to be carried out by United States forces were executed at Culebra, Puerto Rico, by the 1st Marine Brigade, FMF. These exercises involved not only the "assault" landing against a "defended" objective, but also the establishment of effective ship-shore communications, the logistic support of expeditionary forces ashore by the Fleet, and the very elementary beginnings of a practical means of harnessing the immense residual fire-power of ships' guns for accurate employment against shore targets.

As the result of such field tests many new types of landing craft, specially designed for amphibious assault, were developed. These included the "Higgins Boat," which opened at the bow; the amphibian tractor, and other types of landing vehicles. Important improvements also were made in

loading and unloading of troops, equipment, and supplies.

It was in 1935 that the Marine Corps issued its "Tentative Landing Operations Manual," this country's first basic doctrine for amphibious operations. Much of the material in this manual was later adopted by the Army and Navy for training their amphibious units.

From 1935 to 1939 repeated maneuvers and further study provided a means of discovering flaws in practice and theory, and enabled matériel to be put to further tests. When war came in 1941, the United States was in the enviable position of knowing more about amphibious warfare than any other nation in the world. It was this superior knowledge of amphibious landings that was to carry Allied troops over every beachhead of World War II.

During the time that elapsed between Guadalcanal and final victory, many improvements were made in basic landing techniques as a result of experiences, in both the Atlantic and Pacific theaters of war. The most important of these were: the development of a more precise technique for the reduction of tabulated targets, in order of well-determined priorities; a more effective synchronization of naval gunfire and aviation fire in support of landings; elimination of supply bottlenecks; the provision of sufficient landing craft of the proper type, such as the amphibian tractors suitable for crossing reefs; development of a more suitable type of radio equipment and better communications system, and the improvement of the assault technique.

At Okinawa, in the final step before the invasion of the Japanese homeland, these improvements in landing operations enabled the Navy to overcome almost insurmountable problems of isolation and supply in an operation that involved large masses of men and matériel. To successfully conclude this operation, almost a million measurement tons of equipment, supplies, and ammunition were moved on schedule from the Western Hemisphere to the 277,000 United States troops engaged in taking the island.

Following the war, the Marines' traditional status as the developmental agency of United States amphibious technique was recognized in law. The National Security Act of 1947 assigned to the Marines the continued development of tactics and equipment for landing forces. In the future, the Marine Corps, in addition to training its own amphibious forces, will also train Army, Air Force, and Navy amphibious units.

MEDICAL SERVICE, AMPHIBIOUS OPERATIONS

Introduction.—The purpose of this discussion is to present the problems involved in the care of the sick and wounded in a large scale oversea amphibious operation. They will be given in their several phases, to the end that the problems involved as to personnel, equipment, supplies, and provisions for hospitalization and evacuation, ashore and afloat, may be clearly planned in any given operation.

Mission.—In general, the functions of the medical service of an amphibious force are evacuation of casualties, temporary hospitalization, and sanitation in the combat area. Maintenance of the greatest possible number of effectives for duty in all organizations and prompt assumptions in the care of non-effectives are primary missions.

General Tactical Doctrines of Medical Service.—From the mission, characteristics, and responsibilities of the medical service flow certain doctrines governing the employment of medical units. The more important ones are stated below, not for the purpose of limiting the initiative of medical officers but to furnish guides for planning and operating a medical service. Situations will arise wherein the rigid application of one or more of these rules may be inexpedient. Officers and men of all grades are expected to exercise a certain independence in the execution of tasks assigned to them and to show initiative in meeting situations as they arise. However, the experience of the many battlefields in which these doctrines were refined is too impressive to permit them to be dismissed lightly.

Medical service must be flexible. Allotment of medical means is based upon the military situation and the tactical plan obtaining at the time. Changes in the situation may require an immediate redistribution of medical means. An adequate reserve is the most positive assurance of flexibility. So long as the unit commander retains a reserve of combat elements, a commensurate reserve of medical means must be held to support them when they are committed. When his medical reserve has been exhausted, or depleted to the point of inadequacy, it is the first concern of the medical

officer to reconstitute a suitable reserve from units already committed. If this is impossible, he must seek reinforcement. Mobility is another very important element in flexibility.

Mobile medical units must retain their mobility. The essence of medical support is in the maintenance of contact with combat elements. Medical units should retain complete mobility as long as possible by establishing their stations only partially until the demands of the situation require the commitment of their entire means.

The peculiar relationship between patient and physician that distinguishes the civil practice of medicine is incompatible with an efficient military medical service. In civil practice each patient is an entity, and all other considerations are subordinated to the alleviation of his individual disability. This concept of medical responsibility is obviously unsuited to the special conditions that obtain in war. Medical means, always limited, must be so distributed as to render the greatest service to the greatest number. The devotion of a disproportionate amount of time and effort to one casualty can only result in the neglect of many other casualties. The interest of the individual casualty must be subordinated to the interest of the mass of casualties. This is by no means to infer that military medical service should be disinterested or unfeeling. It is rather to insist that it can be really effective only when it is impartial and economical; and, until he fully accepts this point of view, the value of a medical officer is seriously impaired.

Decision and efficient operation of the medical service is a function of command; but it is a staff function to elaborate the technical details necessary to carry the decision into effect. Medical service must be planned and operated in conformity with the specific plans and general policies of the unit commander, and medical plans must be coordinated with other parts of plans. This requires that the medical officer be kept informed of the plans and intentions of the unit commander.

Medical service must be continuous. When an organization is mobilized it requires a functioning medical service. Medical units in sufficient numbers must be given the highest priority in any mobilization or concentration. Sickness occurs during each hour of the day and night, regardless of the location or employment of troops. In combat, the necessity for organized evacuation arises the instant contact is gained.

Of all the tasks of the Medical Department, the most difficult, and in combat, the most important, is the evacuation of casualties. Prompt and orderly evacuation of casualties from forward areas, in a manner least likely to interfere with other military requirements, allows combat units to preserve their mobility and promotes the morale of the remaining effective troops. Force surgeons and medical officers in command of such operations must comprehend the magnitude and the importance of this function. The operation of evacuation of casualties is of the nature of a major withdrawal. In operations against strong resistance as many as one-fifth of all troops engaged, and a much greater proportion of certain elements, may require evacuation within a relatively short period. Under the most favorable circumstances the numbers involved would make the task difficult; but the true proportions of the problem are revealed only by the other factors that must be combated in the operation. These are:

1. The withdrawal must be made against a constant forward flow of troops and supplies, and interference must be kept to a minimum.

2. Evacuees are unorganized, and they must be gathered as individuals from all units of the force. They are not self-supporting but require individual care and treatment through all stages of their withdrawal. A large proportion are unable to walk and must be carried each time they are moved.

3. In forward areas especially, evacuation must be carried on at times under the most trying conditions of weather, terrain, and combat. Conditions which seriously impede all movement may increase the numbers to be evacuated.

Importance of the Problem of Casualties in Planning.—Recognizing, anticipating, and adequately providing for casualties in the basic planning is the key to a sound medical plan.

Experience has shown that, in a large scale amphibious expedition against a stubborn enemy resistance, the casualties from all causes may prove to be a far greater handicap than had been expected. The large number of casualties and the necessity for taking care of them and of making the best practicable disposition of them in the face of inadequate facilities and other difficulties may bog down or even defeat the undertaking. Such a situa-

tion comes about largely because this aspect of the logistics of the expeditionary operations had not been clearly visualized beforehand, and realistically provided for, in the general over-all planning. The probability of its occurrence can be avoided only by a careful study of all factors likely to affect the casualty rate and of other logistic facts bearing directly on this problem, and then, early in planning, providing and properly organizing a sufficient and adequately equipped medical service. Experience likewise has shown that the most difficult, the most sensitive, and the most liable to insufficiency of facilities is the link from the shore line to the home port or other base.

Battle casualty rates, during the landing phases of the operations, may vary from practically nil to 25 percent of the personnel landed. This indicates that in planning, all factors and conditions which may affect the battle casualty rates in the contemplated landing operations must be weighed carefully and that a reasonable factor of safety should be added to the computed requirements of trained medical personnel, regular and auxiliary hospital ships, and of medical equipment and supplies.

In estimating the medical service requirements for a contemplated amphibious oversea expedition against enemy objectives it is necessary to foresee a certain accumulation of casualties afloat. This accumulation is conditioned by two basic factors: the distance from the operations area to the home port or other base, and the elapsed time from the initial landing attack to the day when the amphibious force has firmly established itself ashore with sufficient elbow room for more adequate facilities such as evacuation hospitals. Each of these factors is variable. The effects of the former, however, can be computed in advance with fair accuracy; the latter with far less. In the basic planning, it is therefore necessary to take these factors into consideration and to make a reasonable allowance for an indeterminate initial accumulation of patients afloat. If all hospital ships approved by the expeditionary force commander for the service of the expedition up to the establishment of the hospital facility ashore, do not actually accompany the fleet from the port of embarkation, the greater part of them should do so and the remainder should be scheduled to arrive in the operations area at specified dates shortly thereafter.

Classification of Casualties.—In order to make the best use of available hospital facilities afloat and ashore and to expedite evacuation and treatment, casualties are classified according to:

1. Method of transporting
   a. Walking cases.
   b. Sitting cases.
   c. Litter (stretcher) cases.
   d. Nontransportable.

2. Treatment required
   a. Nontransportable wounded.
   b. Seriously wounded (litter cases).
   c. Slightly wounded (walking or sitting cases).

3. Time of recovery

	Percent
a. Cases returning to duty within 30 days	33
b. Cases returning to duty within 90 days	37
c. Cases permanently lost as a military asset	30

Battle Casualty Expectancy. — Experience has proved that battle casualty rates in a landing operation against enemy resistance may vary from practically nil to 25 percent of the force landed. Losses in individual battalions may amount to 50 percent. Reasonably accurate estimates in advance for the whole amphibious force are difficult. Nevertheless, an estimate must be made early in the planning. The estimate should be based on the best available intelligence data, including:

1. Strength, composition, and armament of the joint overseas expedition.
2. Contemplated methods of carrying out the landing operations.
3. Enemy's naval strength and naval efficiency.
4. Enemy's military strength and locally available military resources; its national military characteristics in defense; probable or possible adequacy and extent of defense armaments, dispositions, and positions.
5. Modern historical experiences in analogous operations.

Necessary data concerning one to four above must be obtained from the proper force planning officers and evaluated by the force surgeon at the earliest possible date.

Sorting of Casualties.—No patient must be permitted to proceed farther to the rear than his physical condition warrants, or the military situation demands. The sorting of the fit from the unfit is a most important function of every medical activity from the aid station to the base hospital. Every case evacuated without sufficient reason imposes an unnecessary burden upon three agencies: the patient's organization, which must go shorthanded until he is replaced; the replacement system, which must procure, equip, train, and transport a man to take his place; and the medical service, which must provide an additional berth in ambulances and trains, an additional bed in a hospital, and additional personnel to care for him. The problem created by one such case is not impressive, but the multiplication of these cases by indifferent sorting of casualties will place a strain upon administrative agencies and may jeopardize the success of the operations. Unnecessary evacuation of patients is of the nature of subsidized straggling. The mere fact that an illness or injury exists is not enough to justify the evacuation of the case. The illness or injury either must be actually incapacitating or of such character that serious consequences may follow if the individual is returned immediately to full duty. This decision is often difficult to make when there is little time for observing the case, and the benefit of all reasonable doubt must be given the patient. However, with proper attention paid to the sorting of casualties, the number of cases evacuated unnecessarily can be greatly reduced.

Concentration of Casualties.—There is an optimum degree of concentration of casualties. It is both uneconomical and inefficient to undertake the care and treatment of the sick and injured in small groups. Successive medical echelons collect casualties from two or more activities in their front until the limit of efficiency in concentration is reached. From this point medical service is expanded by installing parallel chains of evacuation.

Abandonment of Casualties.—Abandonment of living casualties to the enemy is always destructive of morale even when it is not inhumane. In warfare against uncivilized peoples it is not seriously considered even in desperate situations; and this has often been a limiting factor in operations against barbarous tribes. In rapid retrograde movements it is frequently impossible to evacuate all casualties with the facilities at the disposal of the medical service. In such a situation one or a combination of only three courses of action is possible: the speed of the movement may be retarded to permit evacuation with the facilities at hand; the medical service may be reinforced; or the casualties may be abandoned to the enemy altogether with a detachment of medical troops sufficient for their care. This is a command decision. It is the duty of the surgeon to present to the commander the data necessary to help him to arrive at his decision, but the commander alone must decide whether or not to abandon his casualties in whole or in part.

Medical Organization.—Since the responsibility for medical service rests with unit commanders, medical organization must parallel tactical organization.

The effectiveness of medical service frequently is a function of time rather than of thoroughness. Primitive measures, instituted early, often contribute more to the saving of life or limb than more elaborate measures after a delay. This requires that facilities for primary care and treatment be provided within small tactical units.

Sick and injured are not cargo to which the ordinary rules of logistics can be applied. They are perishable; they must be prepared for evacuation; and they require constant care and treatment en route. To effect this a suitable facility to receive them must be located at each point in their journey, from front to rear, where either the character of the transport changes or the responsibility for evacuation passes to another agency. Motor transport has altered the relationship between time and space; but the relationship between time and the ability of a sick or injured man to withstand transportation remains unchanged.

PLANNING AND EMBARKATION

The subject matter of this section envisages the employment of considerable forces of troops, involving landing against opposition. Lesser efforts, as a rule, are simpler to execute and require less extensive preparations.

In the care and handling of the expedition's sick and wounded (hospitalization and evacuation) the medical service has a heavy and very difficult task. Past experience has demonstrated that evacuation of casualties and their temporary hospitalization ashore may become one of the most extensive and difficult of the logistic activities of an amphibious oversea operation. Medical service preparations must therefore be proportionate to the magnitude of the task. Two requirements in amphibious planning must be foreseen and met:

1. An adequate, highly trained directing naval medical staff; and

2. A well-organized and trained naval medical service adequate in personnel, hospital ships, boats, equipment, and supplies.

Oversea evacuation from a large landed force in contact with the enemy where hospitalization has not been established on shore is a delicate and precarious business, very easily thrown into confusion by sea, weather, and enemy interference. A margin of safety is therefore necessary. Organization must be simple and flexible—but complete. Its execution must be in the hands of one man, the force surgeon, assisted by an adequate, trained personal staff working in harmonious relationship with the force planning staff.

When Medical Planning is to be Initiated.—Medical planning and preparation will be initiated early in the planning. The preparation includes procurement, conversion, manning, and special equipping of the required commercial shipping for hospitalization afloat. It should be ready by the date the expedition leaves the port of embarkation. Other medical preparations, though generally requiring less time, must receive early consideration in the basic planning. Hospital-ship beds, necessary or desirable for naval combat, afford no guide to the requirements of a strong amphibious oversea expedition in which floating hospitalization and trained medical personnel must be provided on a much greater scale.

Inherent Limitations.—Medical officers called upon to participate in the medical planning of an amphibious oversea expedition, should understand that their recommendations and estimates of medical requirements, while adequate, should be measured and judicious. Because of the nature of the undertaking, space, personnel, and materiel limitations confront all arms and services in the organization of such an expedition.

Sequence of Preparation and Execution of Plans.—Medical planning divides itself into three phases: planning to include embarkation, planning for the movement overseas, and planning for the operations in the landing area. Since all planning and preparation are for the purpose of executing certain predetermined missions in the landing area, it should be emphasized that the plan for embarkation and movement overseas should be based upon the requirements of the plan covering the actual landing operations.

The evacuation plan must therefore be the first prepared. It is formulated by the force medical staff according to the provisions of the tactical plan as furnished by the proper staff sections, and the estimate of casualties prepared after the evaluation of the information available. The methods by which the estimated casualties are to be cared for in the landing area and the means that must be provided to accomplish the task must also be taken into consideration. These estimated means which must later be converted into form, include personnel, units, and materiel. Having determined the requirements of the medical services for an adequate evacuation system, the embarkation, oversea movement, and landing phases can be planned and provided for in the necessary detail.

In the logical development of planning, the medical plan itself usually will be preceded by the formulation of medical estimate corresponding to the stage of planning reached in the estimate for the expeditionary forces. As a preliminary statement of medical requirements based on staff data which has not yet been developed into the final provisions and form of the plan or the orders of the force commander. This estimate will be less complete and final in provisions and form than the medical plan which will be prepared later from more accurate data based on final command decisions.

The Medical Estimate.—Based on the tactical plan, estimate of casualties and their location, evacuation plan, and estimate of means required by the medical services (supplemented by consultations with the proper officers of the force staff), a medical estimate is prepared by the force medical officer and his staff.

The estimates cover the following basic requirements:

1. Requisite Medical Department personnel and units and their procurement.

2. Additional or special training required for Medical Department personnel.

3. Naval hospital ships, class A and class B.

4. Hospital ships, class D, and their medical equipping, staffing, and manning.

5. Ambulance boats and other boats required by the Navy force surgeon for the efficient control and operation of his service in the landing area.

6. Sanitary requirements and installations in troop ships, and any other special arrangements for the maintenance of the physical condition of troops which will require early action.

7. Standard medical and special equipment.

Before submitting this estimate for approval, it should be carefully reviewed to see that its requirements correspond to the current developments of the expeditionary planning.

It is the duty of the force medical officer to prepare and submit estimates for all medical means which in his judgment, based on full knowledge of the contemplated operations and in the light of past experience, are necessary for the efficient operation of the medical service and for the proper care of the sick and wounded of the expeditionary forces. It is solely the responsibility of the force commander to decide the extent to which these means shall be provided.

Embarkation Phase.

1. Special training for all Medical Department units to be carried out before embarking.

2. Medical units and equipment to be—
   Combat unit loaded.
   Organizational unit loaded.

3. Priorities of embarkation and debarkation of medical units and supplies with notation of assignments to ships.

4. Plan of medical supply.

5. Special measures to insure the health and physical condition of troops up to their arrival in the landing area.

6. Timely inspection of the troop transports and recommendations to insure the provision of adequate facilities for the troops while aboard ship.

7. Embarkation inspection of all troops.

Movement Oversea Phase.

1. Medical care and hospitalization, records, and reports of troops in transports and other ships.

2. Responsibility for sanitary inspections in troop ships.

3. The following medical details which may be finally completed during the oversea movement:

a. Number and classes of patients each ship may receive.

b. Medical supply of each ship.

c. Emergency medical reinforcements for each ship and how they are to be made.

d. Order in which hospital ships are to return to base to discharge patients.

e. Action to be taken should losses exceed expectations and should the capacity of the ships allotted wholly or in part to the medical services be exceeded.

Landing Phase.

1. Debarkation of medical units and equipment in accordance with the force commander's plans.

2. Evacuation from each of the designated landing places.

3. Progressive establishment of medical units, installations, and hospitals ashore, and the organization of the medical service on land, in accordance with the force commander's plan.

4. Evacuation officer (on shore party commander's staff) to be provided with the necessary Army medical commissioned and enlisted personnel and equipment and supplies for—

a. Sorting and handling patients on shore.
b. Reports and records.

5. Progressive utilization ashore of medical personnel, units, and establishments for medical sup-

port of landed forces, beginning with battalion medical detachments with first wave battalions and progressing, as the situation permits, to general hospitalization and other permanent medical establishments.

6. Extension of medical service to all beaches occupied by the forces and to landings made by detached troops.

7. Necessary hospital ships, both Navy and those converted from commercial shipping, in accordance with the approved medical estimate, their equipment and medical complements.

8. Measures for preparing designated troop ships of the expeditionary forces for hospitalizing light casualties in the operations area.

9. Provision of ambulance boats for use in the landing area.

10. Plan of medical supply.

11. Provisions of necessary sanitary installations and other facilities for the maintenance of health and physical condition of all forces in the movement overseas with special attention to troop transports.

IN LANDING AREA

Evacuation From Shore in Landing Area.—The plan for the evacuation service will depend upon the number and relative locations of the landing beaches if there is more than one, which will usually be the case, as well as upon the number and locations of the troop and hospital ships in the landing area in relation to the shore. Widely separated or detached landing beaches require separate allotment of the necessary hospital ships, ambulance boats, personnel, and materiel for evacuation from shore to ship. Hospital ships at anchorage in the landing area are comparable to evacuation hospitals receiving patients from frontline divisions in normal land operations. Beachheads are comparable to division hospital stations; and the boats plying between shore and hospital ships correspond to the Army ambulance companies in the Army scheme of evacuation.

Evacuation Facilities Afloat.—For evacuation from shore to ship the following means are employed:

1. *Small Boats Returning to Ships From Landing Troops.*—The use of these boats in the initial stages of a landing operation for transporting wounded from shore to ship is uncertain and dependent on the military situation. They cannot be thus employed until the essential combatant troops and their equipment have been put ashore. Until the landing is secured, all other activities must yield to this paramount necessity. Thereafter, perhaps later in the first day's attack, these boats on their return trips to ships may carry casualties, preferably the slightly wounded. While being used in this way these boats are not entitled to fly the Red Cross flag or to coverage by the protective provisions of the Geneva Convention.

2. *Ambulance Boats.*—These are motorboats of varying size and design assigned to the operative control of the Navy force surgeon. They fly the Red Cross flag and may be used only for the transportation of casualties, medical personnel, and medical materiel. When thus marked and employed, they are entitled to the protective provisions of the Geneva Convention. The joint medical plan should provide a reasonable number of these boats of approved patient capacity, design, and speed. They should be used primarily for the transportation of seriously wounded cases to hospital ships.

3. *Lighters and Barges.*—Each of these, capable of carrying a large number of wounded on litters or stretchers, should be added to the ambulance boat service in the landing area, to the extent of the requirements, as rapidly as they can be made available after combatant troops and their equipment have been put ashore.

BATTALION LANDING TEAM

Organization and Duties.—a. *The Battalion Surgeon.*—The battalion surgeon serves as a special staff officer to the battalion commander and commands the battalion medical section. His duties include the following:

(1) Supervising the instruction of the battalion in personal hygiene, field sanitation, and first aid.

(2) Making medical and sanitary inspections and keeping the battalion commander advised of the medical situation.

(3) Recommending sites for battalion medical installations.

(4) Personally assisting in the care and treatment of the wounded and performing such other duties as the battalion commander may require.

(5) Organizing the battalion medical section and assigning personnel to appropriate duties.

(6) Conducting as much of the training of the medical section as is not given in conjunction with the combat elements of the battalion.

(7) Submitting requisitions for necessary medical supplies and equipment.

(8) Maintaining records and rendering all required reports.

(9) Preparing the medical plan for the battalion.

(10) Checking the status of supplies during combat and taking measures to insure timely replacement.

(11) Supervising the collection and evacuation of the wounded.

(12) Taking measures to provide medical replacements.

b. *The Assistant Battalion Surgeon.*—The assistant battalion surgeon directs the operation of the battalion aid station and performs such additional duties as may be assigned him by the battalion surgeon.

c. *The Battalion Medical Section.*—The battalion medical section consists of all medical personnel regularly assigned to the battalion. On the basis of duties to be performed, the section divides into company aid men, a litter bearer group, and an aid station group.

(1) *Company Aid Men.*—During combat, hospital corpsmen from the battalion medical section are assigned to the platoons of the three rifle companies in the battalion, normally on the basis of two per platoon. In combat, they are responsible for administering morphine, sulfa, and plasma, for treating hemorrhage, applying splints, and tagging casualties.

(2) *Litter Bearers.*—The litter bearer group of the medical section is designed to meet normal requirements of collecting wounded and evacuating them to the aid station. When the casualty rate exceeds normal, the battalion commander must assign nonmedical personnel to augment the litter bearer group. To this end he should establish priorities among the units of the battalion for providing litter bearer personnel, giving the lowest priority to combat units. The headquarters company will normally receive the highest priority and personnel must be given training in casualty handling prior to operations. Where demands for litter bearers are such that provision of them will adversely affect the combat efficiency of the battalion, the battalion commander makes request to the regimental commander for additional personnel. In order to avoid adversely affecting morale, wounded must be removed from the proximity of combat troops as soon as possible. Every effort must be made to prevent combat troops from leaving their assigned positions to carry or assist wounded to the rear.

(3) *Aid Station.*—The battalion aid station is manned by hospital corpsmen of the battalion medical section, under the direction of the assistant battalion surgeon. Two of the hospital corpsmen serve as contact men in locating wounded and directing litter bearers. The aid station group is capable of setting up and operating two aid stations when necessary, one under the battalion surgeon and the other under the assistant battalion surgeon. Two ¼-ton ambulances are included in the equipment. The specific functions of the aid station include the following:

1. Receiving and recording casualties.

2. Examining and sorting casualties and returning fit to duty.

3. Dressing or re-dressing the wounded, if necessary. (The treatment is limited to that necessary to save life and limb and to prepare patients for evacuation for short distances.)

4. Administering narcotics, whole blood, blood plasma, and toxoids and providing splints.

5. Furnishing prophylaxis and treating shock and exhaustion cases with hot food and drink.

6. Providing temporary shelter for casualties, when possible.

7. Transferring evacuees from the aid station to litter bearers or ambulances of the collecting agency of the supporting medical echelon.

8. Providing replacements for company aid men.

d. *Attached Units.*—During the battalion phase of a landing, a detachment of one-third of a collecting platoon of a collecting and clearing company

is attached to the battalion medical section. Its principal duties are to relieve the battalion medical section of rearward evacuation of casualties from aid station to beach.

Operation.—a. *Planning Phase.*—Prior to embarking for an operation, personnel of the battalion are immunized against diseases. Unfit members of the organization are eliminated and medical personnel, equipment, and supplies are prepared for the operation. The battalion surgeon and the S-4 closely cooperate in preparing plans for embarkation of medical supplies and equipment. A medical plan based on the battalion operation plan and the regimental administrative plan is prepared and normally included in the battalion administrative plan. If sanitation details for the operation require it, an annex to the administrative plan, based on the regimental sanitation plan, is prepared.

b. *Embarkation and Movement Overseas.*—(1) The medical section of the battalion and its materiel are embarked in the same assault transport as the battalion. Company aid men remain with their platoons.

(2) Medical personnel verify the loading of their equipment and supplies, know where the various items are located aboard ship, and are prepared to lower those items requiring it by hand lines during debarkation. Individual equipment, medical packs, litters, blankets, splints, and plasma, and other items to land with medical personnel are stowed in troop compartments or in easily accessible places. Other matériel, including ¼-ton ambulances, is hold-loaded according to its assigned priority. Ambulances are combat-loaded with medical supplies and equipment.

(3) The senior medical officer of the ship is responsible to the commanding officer of the ship for the health, hygiene, and sanitation of all personnel embarked, as well as for the care of troops admitted to the ship's sick bay. The ship furnishes medical supplies and equipment for use on board. Battalion medical personnel assist or supplement ship's medical personnel as is required. During overseas movement, medical personnel of the battalion are thoroughly instructed in their part in the operation.

c. *Landing Phase*—(1) *Ship-to-Shore.*—In the ship-to-shore movement, company aid men are boated with the platoons to which assigned. The battalion aid station personnel are divided into two echelons, separating the two medical officers and forming two aid station groups with battalion litter bearers divided between them. The forward echelon lands with the battalion command group. The rear echelon lands with the battalion reserve. The attached detachment of the collecting platoon lands after the rear echelon of the aid station, preferably in the last wave of the battalion landing team. Casualties occurring during the ship-to-shore movement remain in landing craft for return to ships. Dead are removed to the beach.

(2) *Operations Ashore*—(a) *Company Aid Men.*—Company aid men land with the platoons to which attached. They administer first aid to wounded, direct walking wounded to the beach for evacuation by landing craft or to the battalion aid station when it is established ashore. Non-ambulatory cases are placed in protected positions and their locations marked to facilitate collection by litter bearers when they land. Aid men tag all casualties.

(b) *Forward Echelon of Medical Section.*—Upon landing, this group sets up an aid station in the vicinity of the beach. Litter bearers collect wounded and bring them into the aid station. After the detachment of the collecting platoon lands, and if the rear echelon of the medical section has displaced forward, these litter bearers move forward and join the rear echelon of the medical section. After treatment in the aid station, casualties are again tagged and recorded and are evacuated to landing craft. The battalion surgeon will normally be with this section. An advance detachment of the beach party, which usually includes two hospital corpsmen, will normally be on the beach at this time. They assist in evacuation of casualties to landing craft. Property (litters, blankets, and splints) exchange is effected with landing craft. The aid station of the forward echelon serves as a shore evacuation station and remains in operation until the supporting shore party team lands, when it is relieved by the detachment of the evacuation platoon included in the shore party team. It then displaces forward and consolidates with the rear echelon of the medical section.

(c) *Rear Echelon of Medical Section.*—If the progress of assault units has been rapid it may be necessary for this section to move forward after landing and set up an aid station in close support of assault units. Otherwise it consolidates with the advance

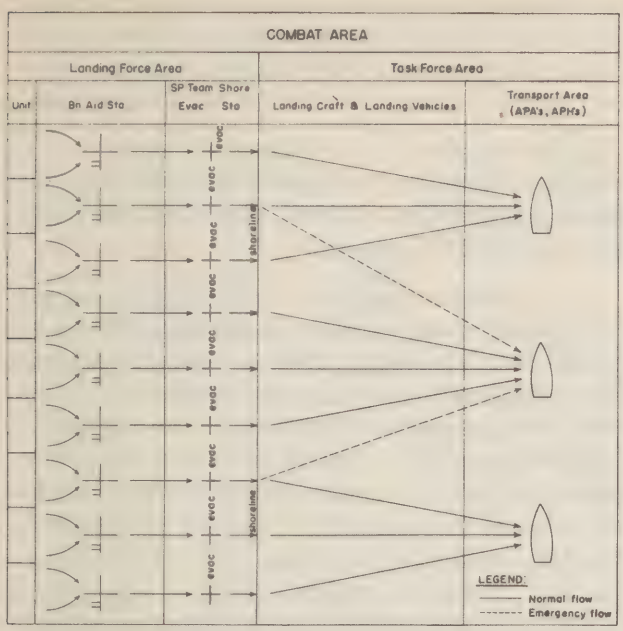


Figure 1.—Flow of casualties in battalion phase of a landing.

echelon near the beach, augmenting the aid station and litter bearers of that section.

(d) *Establishment of Aid Station.*—Advantage is taken of cover, concealment, and camouflage whenever possible in setting up aid stations. Casualties are protected against artillery and mortar fire and against enemy air attacks by such construction of foxholes or air raid shelters as is consistent with the military situation. Abandoned enemy installations are utilized when the situation allows. Care is also taken that all medical installations have adequate security against infiltration tactics of enemy. Since medical installations in forward areas are unable to furnish their own security, they must be so located as to take advantage of the protection furnished by the organization they are serving.

(e) *Detachment of the Collecting Platoon.*—This detachment proceeds to the aid station of the forward echelon on landing. If the rear echelon of the medical detachment has displaced forward, it relieves litter bearers of the advance echelon and evacuates casualties from the aid station of the rear echelon to that of the forward echelon, and from the aid station of the forward echelon to landing craft. Should the medical section be consolidated at the forward echelon aid station, as a result of limited progress by assault units, the detachment of the collecting platoon assists the litter bearers of the medical section in the collection of casualties from forward units. After the shore party team lands, the detachment of the collecting platoon moves forward with the forward echelon of the aid station. Under the supervision of the battalion surgeon it then evacuates casualties from the battalion aid station to the shore evacuation station. It effects property exchange initially between aid stations of the forward and rear echelons, and later between the battalion aid station and shore evacuation station.

f. *Normal Operations.*—When the regimental combat team commander assumes control ashore, medical service in the infantry battalion becomes normal. The battalion commander then controls only the battalion medical section and is responsible only for evacuation from the front to the battalion aid station.

REGIMENTAL COMBAT TEAM

Organization and Duties.—a. *The Regimental Surgeon.*—The regimental surgeon is a special staff officer on the regimental staff and is the representative of the regimental commander for all matters pertaining to the regimental medical service. He commands the medical section of the regiment. His duties within the regiment correspond to those of the battalion surgeon in the battalion.

b. *The Assistant Regimental Surgeon.*—The assistant regimental surgeon assists the regimental surgeon in the preparation of the medical plans and directs the operation of the regimental aid station. He performs such additional duties as may be assigned him by the regimental surgeon.

c. *The Regimental Medical Section.*—The regimental medical section is composed of all the medical personnel organically assigned to the regiment. This section may be divided into two groups, according to the duties which must be performed. These groups are:

(1) *Aid Station.*—(a) The function of the regimental aid station is to provide medical service to the regimental headquarters and such other elements in its vicinity as are not served by the battalion aid stations. It is in the same echelon of evacuation as the battalion aid stations and does not normally form a link in the chain of evacuation from the battalion aid stations. It may, however, take over casualties of a battalion aid station which is forced to move before those casualties can be evacuated. In the early phases of a landing, it may

receive from battalion aid stations casualty overflows which cannot be readily evacuated to the beach.

(b) When the regimental reserve is located near the regimental headquarters the regimental aid station may also serve the reserve, making it possible for medical personnel of the reserve to remain in readiness for movement. In some situations the regimental aid station is not established, its personnel then being available for use as replacement and reinforcement for the battalion medical sections.

(c) The functions of the regimental aid station correspond to those of the battalion aid station. Medical equipment corresponds to that in the battalion, except that three ¼-ton ambulances are included.

(2) *Company Aid Men.*—The company aid men of the regimental medical section perform duties, corresponding to those outlined for the company aid men of the battalion medical section, for the regimental weapons company and regimental service groups.

d. *Attached Units.*—In order to meet the additional responsibility of evacuation to the beach imposed on the battalion and regimental medical sections during the early phases of an amphibious operation, a collecting platoon from a medical company of the division medical battalion is normally attached to the regimental combat team. This platoon is also responsible, during its period of attachment to the regimental combat team, for replenishment of medical supplies for medical units of the regimental combat team.

Operations.—a. *Planning Phase.*—(1) Prior to an amphibious operation the regimental surgeon, in coordination with S-1, eliminates those persons who are not physically fit. At the same time, immunization of all personnel is verified and completed. Medical personnel, equipment, and supplies are brought to a state of readiness.

(2) The regimental surgeon in coordination with S-4 prepares a medical plan based on the regimental operation plan and the division medical plan. A sanitation plan, based on the division sanitation plan, may be prepared and issued as an annex to the regimental administrative plan if sanitation information and instructions are too comprehensive for inclusion in the administrative plan. It may be modified, as necessary, upon landing. To insure satisfactory sanitary standards, all regimental personnel are given adequate training in sanitary measures peculiar to the area of the proposed operation.

b. *Embarkation and Movement Overseas.*—(1) Medical sections of the regiment and their supplies and equipment are combat-loaded with their own units in assault transports.

(2) All medical equipment and supplies are priority-loaded either in the troop compartments or in the holds. Loading plans for medical supplies and equipment are made in coordination with S-4. The equipment with which the regimental medical section is to land is stowed in troop compartments or in an easily accessible place; this includes individual equipment, medical packs, litters, blankets, splints, and plasma. All other medical materiel, including transportation, is hold-loaded according to its proper priority. Transportation is combat-loaded with medical matériel.

(3) The regimental surgeon verifies the loading of medical equipment, and medical personnel acquaint themselves with its location aboard ship.

(4) During movement overseas, personnel of the regimental medical section may be employed to assist medical personnel of the ship in which embarked, as required. Medical personnel are instructed in their duties for the operation.

c. *Landing Phase.*—(1) The regimental medical section debarks and lands in accordance with boat assignment tables prepared by the commanding officer of troops of the vessel in which embarked. The regimental surgeon and an advance echelon of the regimental medical section land with the regimental command group. The remainder of the section lands with headquarters and service company.

(2) The medical detachment with the regimental command group establishes a regimental aid station in the vicinity of the regimental command post. This station is the headquarters from which contact is maintained with battalion medical sections and from which they are reinforced. Casualties occurring in units not operating in the zone of one of the assault battalions are assembled at the regimental aid station and given temporary care. Security considerations in the establishment of the regimental aid station correspond to those for battalion aid stations.

(3) No combatant, unless duly authorized, is permitted to accompany wounded to the rear, and unit medical personnel operate no farther to the rear than the unit aid station.

(4) The regimental combat team commander is responsible for evacuation to the beach in his area from the time he assumes control from battalion landing team commanders until the division commander assumes control ashore.

(5) On assuming control ashore, the regimental combat team commander will have one, two, or three shore evacuation stations in operation depending upon the landing formation of the combat team. Each shore evacuation station is manned by detachments of evacuation platoons of the shore evacuation company.

(6) Detachments of the collecting platoon are consolidated and the platoon operates from the vicinity of the regimental aid station under supervision of the regimental surgeon. Aid stations of all units in the regimental combat team zone of action are cleared of casualties by the collecting platoon which evacuates them to the shore party group shore evacuation station. Ambulances are normally landed in the second trip of landing craft. Those of the collecting platoon are augmented by ¼-ton ambulances of battalions and regiment. These ambulances are used to the limit of traffic, and litter teams of the collecting platoon are used between the point of transfer and the aid stations. The location and situation of the various aid stations are made known to the collecting platoon, through litter bearers and ambulance drivers, by agents of the collecting platoon maintained at each station.

Casualty reports are prepared daily by the regimental surgeon, and are submitted as directed by the division commander.

Normal Operations.—When the division medical facilities are established ashore and the division commander has assumed command of the division ashore, the regimental combat team commander is relieved of the responsibility of rearward evacuation of casualties from battalion and regimental aid stations, and medical service in the regimental combat team becomes normal.

ARTILLERY REGIMENT AND DIVISION TROOPS

Artillery Regiment.—a. Organization and Duties.—Medical sections of the artillery regiment and its battalions correspond in organization and duties to

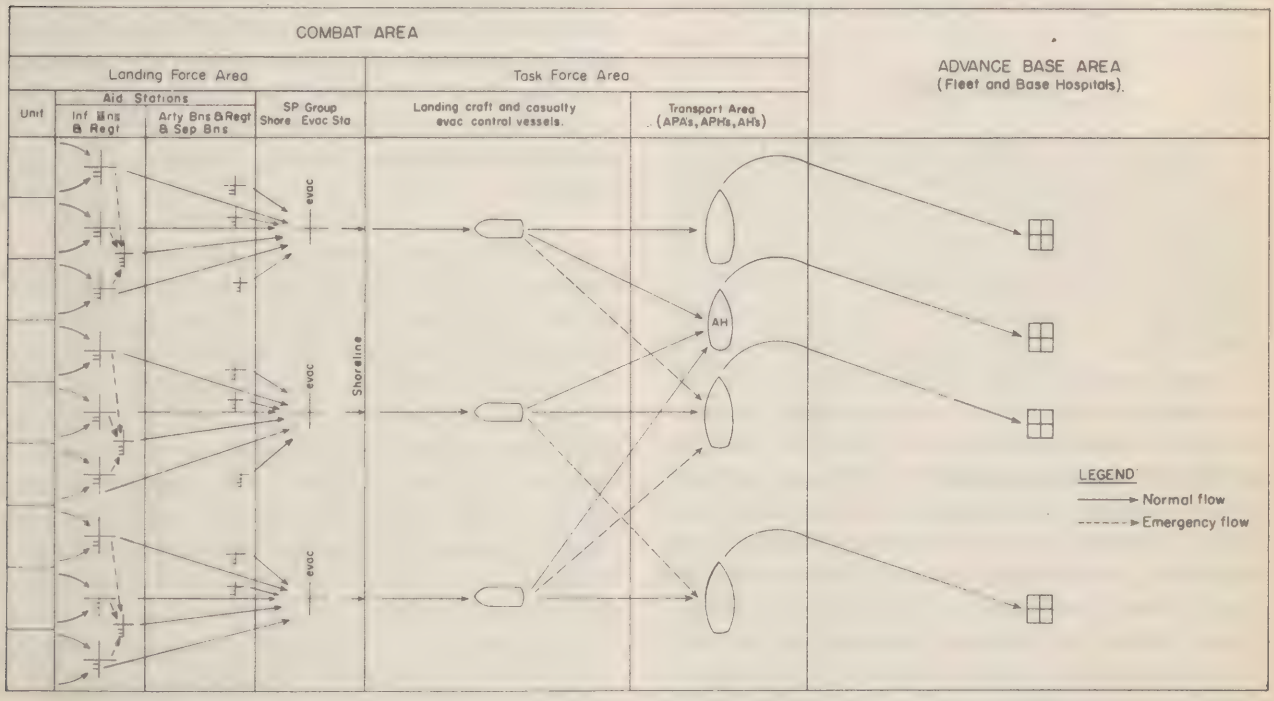


Figure 2.—Flow of casualties in regimental phase of a landing.

medical sections of infantry regiments and battalions. Fewer personnel are included in artillery medical sections because of the lower normal casualty rate in artillery units.

b. *Operation.*—(1) Regimental and battalion medical sections, less battery aid men, are embarked with the headquarters of their respective units and normally land with them. Battery aid men are embarked with their batteries and land with them.

(2) Medical sections establish aid stations ashore which function as in infantry units. Battery aid men remain with their batteries where they provide first aid treatment to casualties and arrange for their evacuation to battalion or regimental aid stations where necessary.

(3) Evacuation of casualties from artillery aid stations is by division collecting platoons, operating either under regimental combat team or division control, to the shore evacuation station of the regimental combat team in whose zone of action the unit is located, or to the nearest division clearing station when those installations are established ashore.

Division Troops.—Battalions of division troops are provided with medical sections comparable to those of artillery battalions. Operation is identical with that of artillery battalion medical sections.

SHORE PARTY

a. During the battalion and regimental phases of a landing operation, shore evacuation stations operated by medical units of the shore party are medical installations in the chain of evacuation and perform the important function of linking the landing force medical service with the task force medical service. This shore party medical service is no longer required after clearing facilities of division medical battalions are established ashore, evacuation to task force medical facilities then being effected by arrangements of division surgeons with appropriate representatives of the task force medical service. Since shore party evacuation of casualties is required only in the battalion and regimental phases, and possibly in the early part of the division phase, the medical organization to carry out this function is contained only in division shore parties, no function of casualty evacuation being required of corps shore party headquarters.

b. In addition to the principal medical service function of shore evacuation, the shore party provides medical service to its own personnel in the form of initial care of casualties, paralleling that provided in battalions, by the establishment and operation of aid stations. Medical personnel are provided for this purpose. (For shore party organization and operation, see PHIB-16, "Amphibious Operations—The Shore Party.")

Organization and Duties.—a. *Shore Evacuation Company.*—This company is an organic part of the division medical battalion. It is organized and equipped to perform the function of shore evacuation of casualties and during the early phases of a landing operation is attached to the shore party. It sets up and operates shore evacuation stations as required by the situation, receiving casualties from landing force units ashore and evacuating those requiring hospitalization to task force facilities at the beach. The company consists of a company headquarters and three evacuation platoons.

(1) *Company Headquarters.*—This consists of a headquarters section and a medical supply section. The headquarters section consists of a medical officer, company commander, a hospital corps officer, administrative assistant, and enlisted clerical assistants for the preparation of records and reports. The company commander is the adviser to the division shore party commander on matters of shore evacuation of casualties during the period the company is attached to the shore party. The medical supply section consists of enlisted personnel with the duties of procurement, custody, and issue of medical supplies.

(2) *Evacuation Platoon.*—(a) This platoon is the shore evacuation unit attached to the shore party group. It is organized and equipped to operate a shore party group shore evacuation station. Equipment is comparable to that of battalion and regimental aid stations. It receives, and evacuates to task force facilities, casualties requiring hospitalization from the zone of action of the regimental combat team the shore party group supports. The platoon consists of a medical officer (platoon commander), two medical officers (shore evacuation station), and enlisted medical personnel to assist in the operation of the shore evacuation station. The platoon commander is adviser to the shore party group commander on matters of shore evacuation of casualties and supervises the operation of

the shore evacuation station. Shore evacuation station officers are charged with operation of the shore evacuation station.

(b) The platoon can be separated into three shore evacuation station detachments, each consisting of one medical officer and one-third of the enlisted personnel of the platoon. Each detachment is capable of operating a small shore evacuation station. One shore evacuation detachment is attached to each shore party team. Their function is evacuation, to task force facilities at the beach, of casualties requiring hospitalization received from units in the zone of action of the battalion landing team which the shore party team supports. The medical officer in charge of each detachment directs the operation of the shore evacuation station and acts as adviser to the shore party team commander on matters of shore evacuation of casualties.

Medical Section, Shore Party Regiment.—This unit has the function of providing first aid treatment to shore party casualties and preparing them for evacuation to shore evacuation stations or division clearing stations if established ashore. It is organized and equipped to form three aid station detachments with a medical officer in charge of each.

Operation.—a. *Battalion phase.*—(1) When the division shore party is ordered to land during this phase, shore party teams for each assault battalion are established on the beach. The battalion landing team commander is responsible for medical service for all personnel in his zone of action during this phase. The shore party team commander is responsible to the battalion landing team commander for the efficient execution of shore evacuation.

(2) When the shore evacuation station detachment lands it relieves the forward echelon of the medical section of the battalion landing team which displaces forward and consolidates with the rear echelon of the medical section. The shore evacuation station detachment sets up its shore evacuation station at the location of the aid station of the forward echelon of the battalion landing team medical section unless this location does not conform to the plan of the shore party team commander, when another site is selected. Security considerations in the establishment of the shore evacuation station correspond to those applying to battalion aid stations.

(3) Casualties are evacuated to the shore evacuation station from the battalion aid station by the detachment of the collecting platoon attached to the battalion landing team or by walking in the case of walking wounded. Shore party casualties are evacuated by shore party personnel, or by walking, to the shore evacuation station. Casualties received at the shore evacuation station are sorted and tagged. Those requiring any degree of hospitalization are prepared for evacuation by landing craft, others are returned to their units. Those to be evacuated are placed in landing craft for evacuation to ships. The shore evacuation station detachment must be thoroughly familiar with task force medical plans in order that the flow of casualties seaward may be regulated in accordance with those plans. Communication between the task force medical service and shore evacuation stations is through the communication facilities of beach parties.

(4) Property exchange with ships is maintained through landing craft by shore evacuation stations. Prompt action to rectify the situation must be taken by shore evacuation officers if ships fail to maintain a proper exchange. Property exchange with the battalion aid station through the detachment of the collecting platoon is also maintained.

b. *Regimental Phase.*—(1) When regimental combat team commanders assume control ashore of their battalion landing teams, shore party teams are consolidated under shore party group control. In order to canalize the flow of casualties to beaches and thus facilitate control of evacuation seaward, evacuation platoons should be consolidated, if the situation permits, and a single shore evacuation station for each shore party group established. If it is impracticable to consolidate the evacuation platoon, the platoon commander coordinates the operations of the shore party team shore evacuation stations as the representative of the shore party group commander, and consolidates reports of evacuations through those stations.

(2) Casualties are evacuated from battalion and regimental aid stations to shore party group evacuation stations by the collecting platoon attached to each regimental combat team. Casualties are processed in the same manner as at shore party team shore evacuation stations and property exchange is continued. Control of the flow of casualties to ships during this phase is assumed by task force medical service personnel in casualty evacuation control vessels off each regimental combat team beach.

(3) Shore party aid stations are established in this phase, one to each shore party group, normally in the vicinity of the shore party group command post. Casualties occurring in the beach area are collected in these aid stations by shore party personnel, and where hospitalization is required they are evacuated to the shore party group shore evacuation station. Evacuation from shore party aid stations to shore evacuation stations is by the collecting platoon attached to the regimental combat team, where practicable, and otherwise by shore party personnel.

c. *Division Phase.*—(1) When there is to be a considerable interval after the division commander assumes control of the division ashore before division clearing stations are set up, the division surgeon assumes control of coordinating evacuation of casualties through shore evacuation stations. Working through the division shore party commander and the shore evacuation company commander, the division surgeon effects further consolidation at shore evacuation stations, if the situation permits, to effect greater canalization of the flow of casualties and thus more efficient control.

(2) After division clearing stations are established ashore, the flow of casualties from all units is diverted to them. The process of evacuation in the division then becomes normal and the shore evacuation company is no longer required by the shore party. It reverts to control of the division medical battalion.

DIVISION

Organization and Duties.—a. *Medical Section, Division Special Staff.*—This section consists of the division surgeon, one hospital corps officer (administrative assistant) and an enlisted clerk. The commander of the medical battalion has additional duty as assistant division surgeon.

(1) *The Division Surgeon.*—The division surgeon is the medical adviser of the division commander and his representative in all matters pertaining to the division medical service. He has no function of command. His duties include the following:

(a) Exercising supervision over all medical activities of the division, including instruction of medical personnel.

(b) Advising the division commander on all matters pertaining to the medical service of the command, and preparing medical plans and orders.

(c) Making recommendations to the division commander on matters pertaining to training, instruction, and employment of non-medical personnel to promote the medical welfare of the command.

(d) Initiating and supervising the execution of measures for the care, treatment, and evacuation of sick and wounded of the command.

(e) Insuring that records are kept and required reports are made by personnel of the division medical service.

(f) Initiating and supervising the execution of sanitary measures.

(g) Making recommendations to the division commander of measures for the control and prevention of disease.

(2) *The Administrative Assistant.*—This officer, member of the Medical Service Corps, assists the division surgeon by the performance of such administrative duties of the division surgeon's office as may be assigned him. An enlisted clerk is assigned to assist him in the performance of his duties.

b. *Medical Battalion.*—This battalion consists of a headquarters and service company, a shore evacuation company, three collecting and clearing companies, and two hospital companies. It is organized and equipped for flexibility in meeting the varied and specialized conditions incident to amphibious operations.

(1) *Headquarters and Service Company.*—This company is composed of the battalion and company headquarters, the division medical supply section, the malaria and epidemic control section, and the dental section. The company is organized and equipped to conduct normal administrative and service functions of the battalion. It is the medical supply agency for all medical units of the division. Specialized medical service personnel are included in the unit. The company is commanded by the battalion executive officer.

(a) *Battalion and Company Headquarters.*—This headquarters contains all the personnel necessary for administrative duties of the company and battalion. It includes the battalion commander, battalion executive officer, an administrative assistant, the division medical supply officer, the division

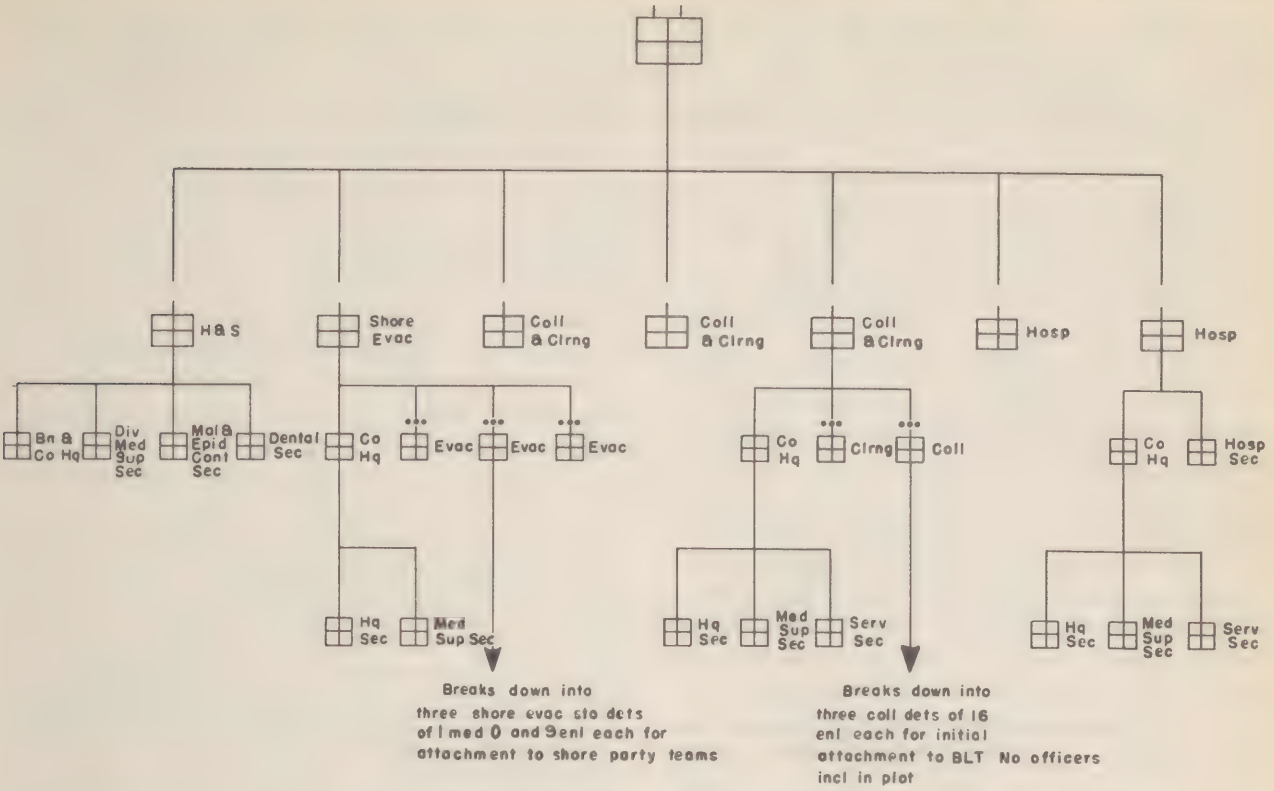


Figure 3.—Organization of the division medical battalion.

psychiatrist, and necessary enlisted personnel for clerical and service duties. The battalion commander is responsible to the division commander for the training, administration, and operations of the battalion. He has additional duties as assistant division surgeon. In the latter capacity he assists the division surgeon in the preparation of medical plans and estimates and performs such other duties as may be assigned him by the division surgeon. The executive officer assists the battalion commander in the performance of his battalion functions and also performs the duties of battalion plans and training officer. He has the additional duty of evacuation officer and as such coordinates the evacuation of casualties in the division and supervises the preparation of casualty and evacuation reports by the division medical record section. The division medical record section is composed of enlisted clerical personnel of the battalion and company headquarters. The administrative assistant is a hospital corps officer who is a specialist in administrative work. He has direct supervision of the operation of personnel of the battalion and company headquarters who are concerned with clerical and service duties pertaining to the medical battalion. The division medical supply officer is a hospital corps officer assigned the duty of directing and supervising the procurement, storage, and transportation of medical supplies and equipment and their distribution to all medical units of the division.

(b) *Division Medical Supply Section.*—Personnel of this section consists of a chief hospitalman and subordinate enlisted personnel. Under the direction of the division medical supply officer, the section is charged with the details of procurement, storage, and distribution of medical supplies and equipment for the division.

(c) *Malaria and Epidemic Control Section.*—This section consists of a medical officer, assistant to the division surgeon and chief of section, three medical or medical service corps or hospital corps officer and enlisted assistants. All personnel are specially trained in epidemic control measures. They are provided with laboratory equipment necessary for the study of conditions in the area in which the division is located. The malaria and epidemic control officer makes recommendations to the division surgeon on measures to safeguard the command against malaria or other diseases common to the area, and supervises the execution of these measures.

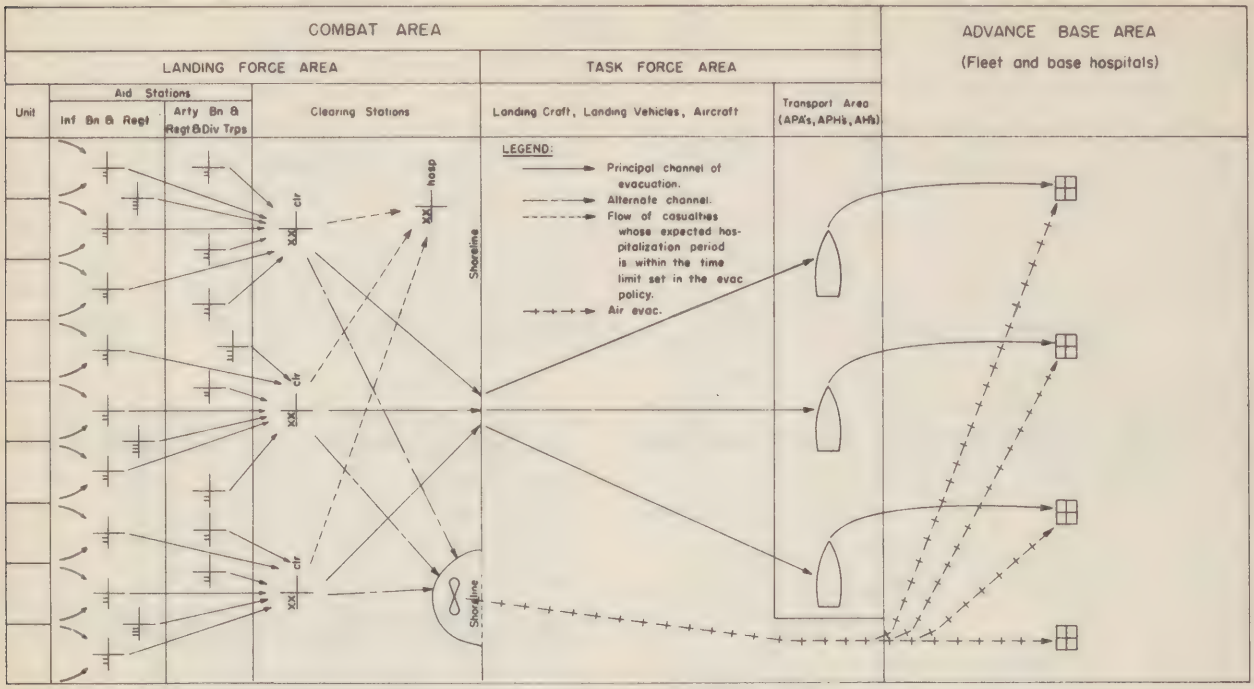


Figure 4.—Flow of casualties in division phase of a landing. Casualties are being diverted from one supporting medical company in order to prepare it for forward displacement.

(d) *Dental Section.*—This section consists of dental corps officers and enlisted assistants. The section is charged with the dental care of personnel of the division, augmenting that provided by dental officers of regimental medical sections and collecting and clearing and hospital companies. Personnel of this section normally do not accompany the battalion into combat but remain with the rear echelon of the division.

(2) *Collecting and Clearing Company.*—This company consists of a company headquarters, a clearing platoon, and a collecting platoon. The functions of the company are to operate a clearing station and to evacuate casualties within the division.

(a) *Company Headquarters.*—This headquarters consists of a headquarters section, a medical supply section, and a service section. The headquarters section includes a medical officer, company commander, a hospital corps officer, administrative assistant, and enlisted personnel with company administrative duties. The company commander is responsible for the training, administration, and operations of the company. Company administrative personnel function under the supervision of the administrative assistant. Their functions include the preparation of medical records on casualties received and cleared through the clearing station. The medical supply section consists of enlisted personnel with the duties of procurement, storage, and issue of medical supplies for the company. The service section includes enlisted personnel performing the various service functions in the company. Ambulance drivers and ambulances which operate with the collecting platoon are included in this section. One air-conditioned mobile hospital operating room trailer for use of the clearing platoon is included in the service section.

(b) *Clearing Platoon.*—This platoon includes three medical officers, two of whom are surgeons, a dental officer, and enlisted medical personnel consisting of special technicians and personnel for routine ward duties. The platoon is organized and equipped to set up and operate a 60-bed clearing station. The clearing station receives casualties from units of the division which the company is assigned to support and clears them in accordance with the evacuation policy to task force facilities or to the division hospital. It is prepared to perform emergency life-saving surgery using the mobile hospital operating room trailer, or where use of this trailer is impracticable, using field surgical equipment.

(c) *Collecting Platoon.*—This platoon is composed entirely of enlisted medical personnel. It operates under the immediate direction of the com-

mander of the collecting and clearing company when the company is operating as a unit. The duties of the platoon are the collection of casualties from aid stations of units which the collecting and clearing company supports and the evacuation of these casualties to shore evacuation stations or to the clearing station, in accordance with the situation ashore, and from the clearing station to the beach or division hospital. The platoon can be separated into three detachments for attachment to battalion landing teams in the early phases of a landing. Personnel are trained in litter bearing and other casualty handling methods. Ambulances, included in the service section of the company headquarters, operate with the collecting platoon.

(3) *Hospital Company.*—This company consists of a company headquarters and a hospital section. Its function is to provide hospitalization ashore for division casualties which, in accordance with the evacuation policy, are not to be evacuated to task force facilities, and during periods when the tactical situation or other conditions prevent evacuation to task force facilities, to provide hospitalization for all division casualties. The headquarters and service company with its administrative facilities and the two hospital companies are normally combined to establish the division hospital.

(a) *Company Headquarters.*—This headquarters consists of a headquarters section, a medical supply section, and a service section as in the company headquarters of the collecting and clearing company. Functions of the headquarters and its subordinate sections correspond to those of the company headquarters of the collecting and clearing company. Ambulances of the company are included in the service section.

(b) *Hospital Section.*—This section is organized and equipped to set up and operate a 200-bed hospital. Organization is similar to that of the clearing platoon of the collecting and clearing company except that more medical personnel and hospital facilities are included in the hospital section.

Operation.—a. Planning Phase.—(1) Early in the planning phase the division surgeon must have access to corps operation and administrative plans so that he may make timely arrangements for procurement of supplies and equipment and begin preliminary planning. He keeps abreast of division operational and administrative planning so that he may formulate the medical plan and disseminate medical information in ample time for all subordinate units to make necessary plans.

(2) Basing it on the division operation plan and his medical estimate of the situation, the division surgeon formulates the medical plan which is issued as an annex to the division administrative plan. (For medical annex form, see *Staff Manual,* U.S. Marine Corps.) He must work closely with the staff medical office in the preparation of this plan to insure coordination of medical details with other details of the administrative plan. The division medical plan, in general, sets forth the medical organization for the operation, indicating attachments of division medical elements to regimental combat teams, the employment of the division medical battalion, and details as to medical supply, evacuation, hospitalization, and sanitation which are not covered by standing operating procedure. A sanitation plan may be prepared as an appendix to the medical annex if sanitation information and instructions are too extensive for inclusion in the medical plan.

b. *Embarkation and Movement Overseas.*—(1) Prior to embarkation, the division surgeon coordinates with the staff medical officer in preparing the division embarkation plan to insure that units of the medical battalion are properly embarked, and medical supplies and equipment are given the required priority in loading to insure proper execution of the medical plan. (One collecting and clearing company is included in the embarkation group of each regimental combat team, although this company is not normally included in the task organization of the regimental combat team for operational purposes.) The collecting platoon from each collecting and clearing company, however, is included in the task organization of each combat team for the landing. The headquarters and service company and the two hospital companies are embarked in the same embarkation group, but on separate ships, when possible. This embarkation group is preferably the one including division headquarters. By timely supervision, the division surgeon insures that embarkation of medical units, supplies, and equipment is carried out in accordance with embarkation plans.

(2) To insure continuity of medical supply ashore during the landing, all medical vehicles are embarked loaded with supplies and equipment in

accordance with the probable demand for their use. Collecting platoons attached to regimental combat teams normally carry, loaded in ambulances and elsewhere, 20 percent of the medical supplies allotted to their collecting and clearing companies in order to insure early re-supply to battalion and regimental medical detachments of the regimental combat teams to which they are attached.

(3) During movement overseas, division medical units provide necessary assistance to medical personnel of the ships in which embarked.

c. *Landing Phase.*—(1) *Initial Situation.*—The division surgeon, his administrative assistant, the medical battalion commander, evacuation officer and medical record section personnel normally land with the division headquarters. At this time there are in operation shore party group shore evacuation stations for each shore party group, or shore party team shore evacuation stations for each shore party team, if consolidation by shore party group commanders has not been accomplished. When the division commander takes command of the division ashore, the division surgeon assumes control of coordination of casualty evacuation through shore evacuation stations. Evacuation reports of shore evacuation stations are submitted for consolidation to the division medical record section at the division shore party command post. The medical battalion commander reconnoiters previously selected initial locations for clearing stations and determines their suitability, selecting new locations where the situation dictates. He also selects a suitable location for the division hospital. As soon as the situation ashore provides reasonable security for their establishment, he recommends to the division surgeon that one or more of the collecting and clearing companies, less collecting platoons attached to regimental combat teams, be landed. If the division surgeon concurs in the recommendation of the medical battalion commander, he in turn makes a similar recommendation to the division commander who directs issue of the necessary orders.

(2) *Clearing Stations.*—(a) When collecting and clearing companies, less collecting platoons, land they move to positions indicated by the medical battalion commander and set up clearing stations. One company is normally assigned in support of each regimental combat team, except where the anticipated casualty rate of a reserve regimental combat team does not require setting up a clearing station in its support, when one company may be held mobile prepared for forward displacement. In such case, casualties for the reserve regimental combat team are evacuated, as directed by the division surgeon, to clearing stations of collecting and clearing companies in support of the two assault regimental combat teams. When clearing stations are established, collecting platoons revert to control of their parent companies and the flow of casualties is diverted from shore evacuation stations to clearing stations. Orders are issued to all units indicating the time and place of opening of clearing stations. Casualties from all units located in the zone of action of a regimental combat team are evacuated to the clearing station of the collecting and clearing company supporting that regimental combat team. Casualties from division troop units are evacuated to the nearest clearing station, or to clearing stations as directed by the division surgeon.

(b) When clearing stations are in operation the need for shore evacuation stations no longer exists and they are dissolved. The shore evacuation company reverts to medical battalion control where it constitutes a pool of personnel and equipment available as replacements or reinforcements to medical units of the division. The division medical record section moves to the vicinity of the division command post. Wire communication between the medical record section and clearing stations should be established as soon as possible.

(c) Casualties are received at clearing stations and sorted. Those requiring hospitalization are prepared for further evacuation to the beach. Others are returned to their units. Where indicated, emergency lifesaving surgery is performed. Minimum hospitalization is provided in clearing stations and then only in cases where further evacuation would endanger the patient's life. Reports of all evacuations from clearing stations, together with other medical reports, are submitted to the division medical record section.

(d) Coordination of evacuation of casualties from clearing stations is by the division evacuation officer under the direction of the medical battalion commander and supervised by the division surgeon. Clearing stations are not permitted to become immobilized by an accumulation of casualties. The division surgeon arranges for regular evacuation of

casualties by landing craft to the task force medical service. Through the medical battalion commander he keeps informed of the number and status of casualties in clearing stations and through the medical battalion commander, directs commanders of collecting and clearing companies to evacuate casualties in numbers specified to a designated beach at a prescribed time where they are transferred to landing craft for further evacuation to ships. The evacuation officer directly supervises this transfer operation and checks casualties against evacuation reports of clearing stations. A consolidated report of casualties evacuated is turned over to the task force medical representative with the landing craft.

(e) Employment of collecting and clearing companies is flexible. The medical battalion commander controls the flow of casualties into clearing stations in order to avoid overloading any one of them and to prepare designated companies for forward displacement as the attack advances. When it is decided to displace forward a collecting and clearing company, the flow of casualties into the clearing station of that company is diverted to the clearing stations of the other two companies and casualties on hand are evacuated to the beach or the division hospital, if in operation, as the status of the casualties indicates.

(3) *Collecting Platoons.*—Collection and evacuation of casualties in the division is by collecting platoons of collecting and clearing companies. These units, operating under the direct supervision of commanders of collecting and clearing companies, evacuate casualties from infantry battalion and regimental aid stations, shore party aid stations, and aid stations of division units, employing ambulances supplemented by litter bearers, where necessary. Collecting platoons maintain liaison by means of agents with aid stations of units their company supports. Through litter bearers and ambulance drivers, these agents keep collecting platoons informed of the status of casualties in the aid stations and of projected movements of aid stations, with future locations. Other means of communication are employed where available. Where adequate collection of casualties is not maintained, it is the responsibility of the battalion or regimental surgeon concerned to take the necessary action to correct the situation, by informing the commander of the responsible collecting and clearing company, the medical battalion commander, or the division surgeon. Quarter-ton ambulances of regimental and battalion medical sections may be attached to collecting platoons since there are few situations where ambulances can evacuate casualties from locations forward of aid stations, except in the cases of rear units. Collecting platoons evacuate casualties from clearing stations to the beach and to the division hospital when it is in operation. Property exchange is effected by collecting platoons with aid stations and with the task force medical service at the beach. The latter is under supervision of the division evacuation officer.

(4) *Division Hospital.*—When progress of assault units is such that an adequate area providing security from fire of most hostile weapons is available, the headquarters and service company and the two hospital companies are landed on the division commander's order and the division hospital is established ashore at the location selected by the medical battalion commander. In some situations the medical battalion, less collecting platoons, may be landed simultaneously. Advantage is taken of abandoned enemy buildings and installations where found, provided they offer adequate security and are not prominent landmarks. One hospital company is normally held mobile prepared for forward displacement or emergency, if the casualty rate at the time of landing does not require setting up of both companies. The division hospital receives from clearing stations casualties whose required period of hospitalization is within the limit prescribed in the evacuation policy. Classification of casualties with respect to the evacuation policy is effected at clearing stations. The division hospital is not normally in the principal chain of evacuation of the division. Should the tactical situation require withdrawal of ships of the task force from the combat area, or should weather conditions prevent seaward evacuation of casualties, evacuation ashore is then from clearing stations to the division hospital. Ambulances of hospital companies may be used to augment those of collecting platoons. When the division hospital is established ashore, medical service in the division becomes normal.

AMPHIBIOUS CORPS

Organization and Duties.—a. *Medical Section, Corps Special Staff.*—This section consists of a medi-

cal officer, corps surgeon, a medical officer, assistant corps surgeon, a Medical Service Corps officer, administrative assistant, a chief pharmacist's mate, and three subordinate enlisted personnel.

(1) *The Corps Surgeon.*—Like the division surgeon, the corps surgeon is a special staff officer and bears the same relation to the corps commander as the division surgeon does to the division commander. Duties of the corps surgeon are analogous to those of the division surgeon, except that the corps surgeon is also the corps evacuation officer. When the corps commander is landing force commander, the corps surgeon has the additional duty of coordinating the medical service of the landing force with that of the task force, both in planning and in operation.

(2) *The Assistant Corps Surgeon.*—This officer assists the corps surgeon by performing such duties as may be assigned him by the corps surgeon.

(3) *The Administrative Assistant.*—This officer is charged with direction and supervision of the administrative work of the corps surgeon's office. The four enlisted personnel of the section assist him by performing clerical duties.

b. *Medical Sections of Corps Troops.*—Separate battalions included in corps troops are provided with medical sections whose organization and functions correspond to those of battalions of divisions.

c. *Corps Medical Battalion.*—This unit is composed of a headquarters and service company and three identical medical companies. Its primary function is to reinforce the medical service of divisions. It evacuates casualties from aid stations of corps units and provides temporary hospitalization to casualties received.

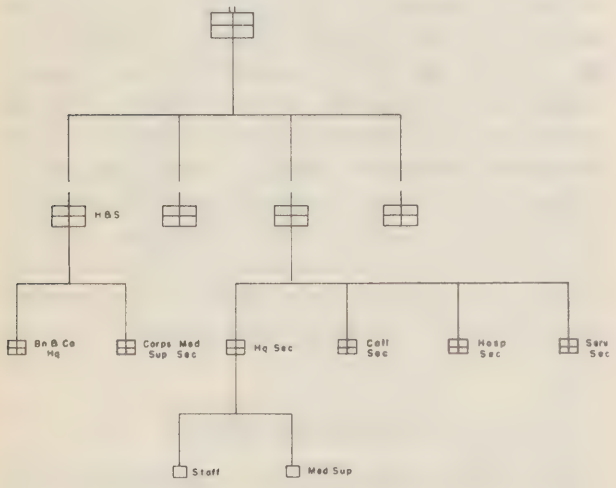


Figure 5.—Organization of the corps medical battalion.

(1) *Headquarters and Service Company.*—This company corresponds to the division headquarters and service company with the exception that no malaria control or dental sections are included. Functions of the company and duties of personnel correspond to those of the division headquarters and service company.

(2) *Medical Company.*—This unit consists of a headquarters section, hospital section, collecting section and service section. It is a mobile field unit with organic collecting and service facilities. Being a complete functional unit, it may be detached from the medical battalion for independent duty and may function as a mobile field hospital if required. Company personnel includes medical officers, one of whom is company commander, a dental officer, a hospital corps officer, administrative assistant to the company commander, and enlisted personnel for the performance of specific administrative duties.

(a) *Headquarters Section.*—This section is divided into two groups; staff and medical supply. The staff group contains the administrative personnel of the company—the company commander, his administrative assistant, and necessary enlisted personnel. The medical supply group consists of enlisted personnel whose duties are procurement, storage, and issue of medical supplies to the medical battalions and separate battalions of corps troops.

(b) *Hospital Section.*—This section is organized and equipped to set up and operate a 144-bed field hospital. It has necessary field surgical equipment for the performance of all types of surgery. A mobile operating room trailer may be attached from the headquarters and service company. Section personnel include necessary medical officers, a dental officer, and enlisted assistants and technicians.

(c) *Collecting Section.*—This section is organized and equipped for the collection of casualties in corps troops and for augmenting the collecting facilities of divisions when attached to those units. Ambulances of the medical company are operated by this section and personnel of the section are trained in litter-bearing and other casualty handling methods.

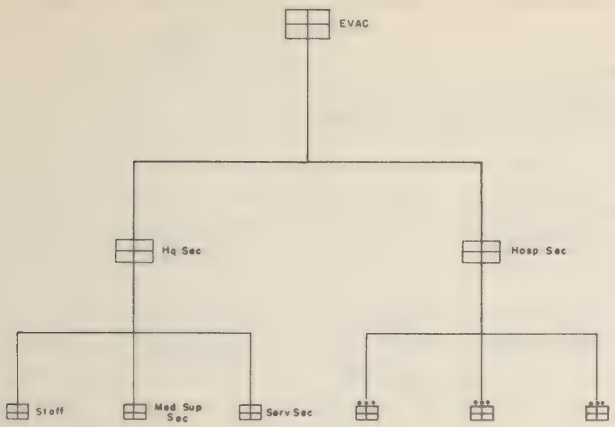


Figure 6.—Organization of the corps evacuation hospital.

(d) *Service Section.*—This section is composed of enlisted personnel for administrative duties. Included are mess personnel, clerks, electricians, motor mechanics, and ambulance and truck drivers.

d. *Corps Evacuation Hospital.*—This unit is a Fleet Marine Force unit which may be attached to corps for operations. It consists of a headquarters section and a hospital section which is composed of three similar platoons, each of which is organized and equipped to provide the same type of service. Specialized medical and surgical care not provided in other medical units of corps or divisions is provided by this unit in the cases of casualties where evacuation to hospital ships would preclude the the obtaining of satisfactory results. Contrary to its title, the unit has no function of corps evacuation.

Operation—a. *Planning Phase.*—(1) Medical planning is carried out in the same manner in the corps as outlined for the division. Preliminary planning is begun upon receipt of the medical plan of the landing force, or of the task force where the corps is the landing force.

(2) When the corps commander is the landing force commander, the corps surgeon works closely in this phase with the task force medical officer in the coordination of landing force and task force medical plans. Additional planning details, such as air evacuation, must be coordinated in plans of the two medical services. The corps medical plan includes the general plan for evacuation and hospitalization in the corps together with such details as to employment of the corps medical battalion and corps evacuation hospital as are not included in standing operating procedure.

b. *Embarkation and Overseas Movement.*—Medical operations in this phase correspond to those outlined for the division medical service.

c. *Landing Phase.*—(1) The corps surgeon will normally land with the corps headquarters. When the corps commander takes command of his divisions ashore, the corps surgeon assumes control of coordination of the evacuation of casualties from divisions. Prior to establishment ashore of the corps medical battalion and the corps evacuation hospital, the corps surgeon arranges for the evacuation of casualties over specified beaches, at specified times, to landing craft. If air evacuation facilities are available he controls the evacuation of casualties by air in accordance with the task force policy and the availability of aircraft, and in coordination with the task force air evacuation medical officer. The corps surgeon reconnoiters for and selects suitable sites for the corps medical battalion and the corps evacuation hospital.

(2) Medical sections of the separate battalions of corp troops land with their battalions. They set up aid stations ashore and operate as previously described for battalion medical sections. Prior to landing of the corps medical battalion, casualties requiring hospitalization which occur in units of corps troops are either evacuated to the nearest division medical installation, or to beaches for evacuation by landing craft to ships, in accordance with the condition of the casualty, and as arranged by the corps surgeon.

(3) When the progress of operations of the landing force permits, the corps medical battalion and the corps evacuation hospital are ordered ashore by the corps commander. Priority in landing is given the corps medical battalion. One company of the medical battalion normally sets up a hospital for the temporary hospitalization of casualties from corps troops units. The other medical companies are held mobile prepared to reinforce the medical service of divisions if required. Casualties are evacuated from aid stations of corps troops by the collecting section of the medical company in operation. This company also serves as a clearing station for corps troops, and casualties requiring hospitalization beyond the period specified in the evacuation policy are evacuated to landing craft at beaches or to air evacuation units as directed by the corps surgeon. Records of casualties evacuated are submitted to the corps surgeon's office.

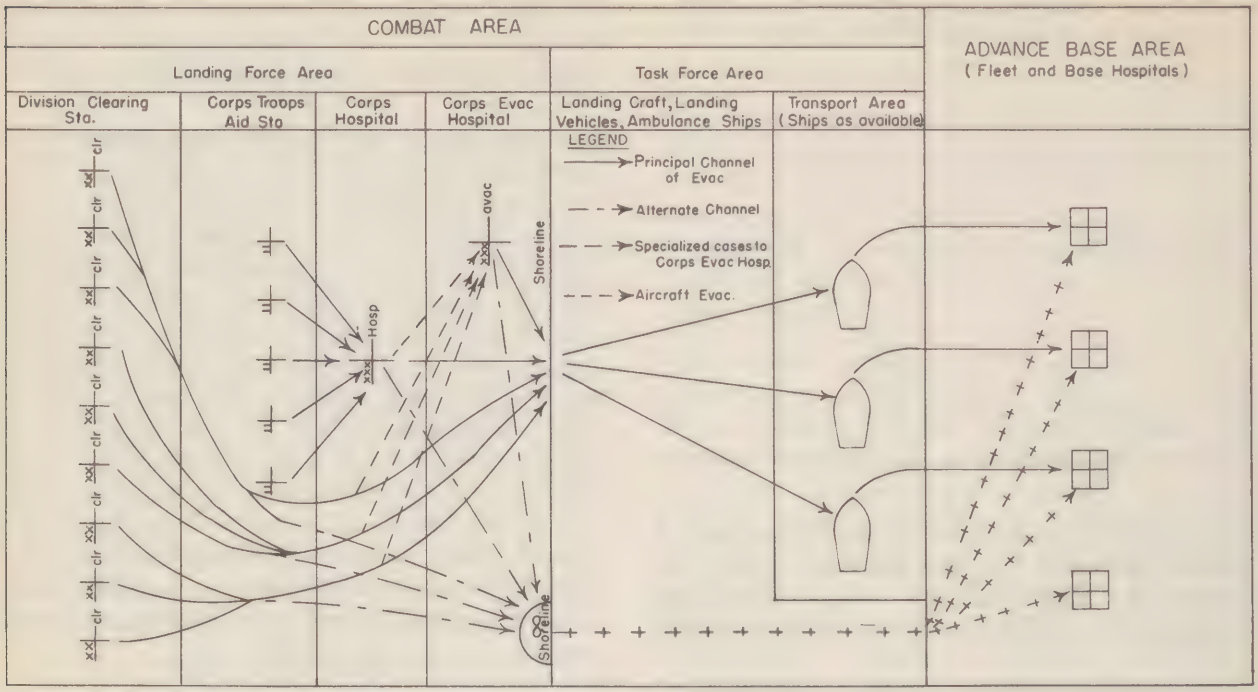


Figure 7.—Flow of casualties in corps phase of a landing.

(4) When the corps evacuation hospital is established ashore, casualties from divisions and corps troops requiring immediate, specialized medical care are evacuated to that installation. Casualties in the corps evacuation hospital, whose condition permits further movement and who require additional hospitalization beyond the period set in the evacuation policy, are evacuated by ambulances of the corps evacuation hospital to landing craft at beaches or to air evacuation units as directed by the corps surgeon. Record of casualties evacuated is submitted to the corps surgeon's office.

(5) Corps medical units do not form a link in the principal chain of evacuation. The corps surgeon is the evacuation officer of the corps and directs and supervises the evacuation of all casualties from the corps to task force facilities. Casualty evacuation records of divisions are forwarded to the corps surgeon's office for consolidation.

(6) When aircraft landing facilities are available, casualties from divisions and corps troops are evacuated to aircraft landing areas in accordance with instructions issued by the corps surgeon in the light of the task force air evacuation policy and instructions of the task force medical officer, specifying types of casualties, numbers allotted to each subordinate unit, and time of delivery at the aircraft landing area. The corps surgeon, or his representative, supervises the transfer of casualties to the air evacuation unit.

TASK FORCE

Organization and Duties.—a. (1) The organization of the medical service of an amphibious task force varies in size and details of composition with the medical requirements for each particular operation as determined by a medical estimate of the situation. Medical facilities normally consist of those provided by assault transports, assault transport hospital ships, and hospital ships. Special types of vessels, such as tank landing ships and vehicle landing ships (LSV's) may be especially equipped to carry out functions of the medical service, such as temporary hospitalization, casualty traffic control, and ambulance assignments. Aircraft for evacuation of casualties may be provided by the theater commander in accordance with task force plans, or as requested by the task force commander.

(2) The functions of the task force medical service are as follows:

(a) To provide medical service for all attached

and embarked personnel between embarkation points and landing beaches.

(b) To evacuate casualties from beaches to ships and to provide temporary hospitalization afloat in the combat area.

(c) To evacuate casualties by ship and aircraft from the combat area to fleet and base hospitals in the theater of operations.

b. *The Task Force Medical Officer.*—The senior medical officer on the task force staff is the representative of the task force commander for all matters pertaining to the medical service of the task force. He determines the medical facilities required for a projected operation and prepares the task force medical plan. During operations he acts as task force evacuation officer and coordinates the operations of all components of the medical service.

c. *The Amphibious Group Medical Officer.*—The amphibious group is composed of the transport squadron embarking a division of the landing force, and such naval gunfire and air support groups as may be assigned. The medical officer on the staff of the group commander is responsible for execution of the following duties:

(1) To organize and train the medical elements of the command for operations.

(2) To prepare plans for the operation of the medical service of the group based on the task force medical plan and the group operation plan, with particular emphasis on measures to obtain equitable distribution of casualties to ships designated as hospital ships.

(3) To coordinate the medical services of subordinate elements during operations.

(4) To provide a liaison officer with the landing force evacuation officer to act as an adviser on seaward casualty evacuation, air evacuation, and other matters pertaining to the task force medical service.

(5) To assign assistants to the casualty traffic control organization as advisers to the traffic control officers and to maintain records of the seaward casualty flow.

d. *Other Staff Medical Officers.*—Staff medical officers of transport squadrons and transport divisions are responsible for preparing details of execution of medical service within squadrons and divisions as prescribed in the medical plan of the amphibious group. They advise their commanders on the status of medical service in the command and act as evacuation officers of their echelons.

e. *Organization of Medical Facilities.*—(1) *Assault Transports and Assault Transport Hospital Ships.*—Medical plans designate certain transports in the various subordinate echelons of the task force for duty as hospital ships in the landing phase. Any assault transport hospital ships included in the task force will normally be assigned to this duty. Other transports are assigned duty as hospital ships for prisoner of war casualties. The number of transports and transport hospital ships assigned duties as hospital ships is based on the estimated casualty rate for the operation. When facilities of ships designated for hospital duty become taxed, other ships may be designated for this duty. Transports are prepared to care for casualties requiring any type of treatment ranging from emergency first aid to life-saving surgery and, when necessary, definitive surgical measures. Assault transport hospital ships are specially equipped to provide hospital facilities over and above those provided by assault transports. They are staffed with specialized medical personnel. Landing craft of all transports are used to evacuate casualties from shore to ships.

(2) *Hospital Ships.*—These ships are specially designed and equipped for hospital purposes. They have a full staff of medical officers, including various types of specialists. Medical services afforded are superior to those provided by assault transport hospital ships. They normally operate directly under the task force commander and usually enter the combat area when conditions are favorable after the initiation of the landing operation. In accordance with medical plans, casualty evacuation control groups direct certain types of casualties to hospital ships.

(3) *Specially Equipped Vessels.*—(a) Tank landing ships designated by the task force commander may be provided with additional medical equipment and staffed with required medical personnel for casualty evacuation control duties. During the early phases of the landing one of these ships is normally assigned to each transport division embarking an assault regimental combat team. When the situation ashore permits, it takes station off the combat team landing beach, sorts casualties in landing craft returning from the beach to ships,

directs the landing craft to specific ships having hospital duties, and, when circumstances require, removes casualties from landing craft to the tank landing ship for the performance of emergency life-saving surgery. These tank landing ships are assigned radio frequencies on special nets whereby they may keep informed of the casualty capacity status of the various hospital ships and receive special instructions regarding direction of the flow of casualties to hospital ships. When conditions permit, tank landing ships may be employed as ambulance ships for the evacuation of casualties directly from the shore to hospital ships. Where the distance to advance base hospital facilities is short, they may be equipped to serve as hospital ships.

(b) Vehicle landing ships may also be equipped to perform some of the functions outlined for tank landing ships.

(4) *Aircraft.*—Use of air transport for evacuation of casualties is usually provided for in the medical plan. These facilities, normally under the theater commander, are made available at advance bases to be on call by the task force commander when landing fields, or seaplane landing areas, are available. Aircraft are specially equipped for evacuation of casualties, and flight medical personnel are provided.

Operation.—a. *Planning Phase.*—Based on plans of higher headquarters, the task force operation plan, and the medical estimate of the situation the task force medical officer makes recommendations to the task force commander as to the medical facilities required by the task force medical service properly to support the operation. When a decision has been reached on this, the task force medical officer formulates the medical plan. This is done after conferences with the landing force surgeon and medical officers of subordinate elements of the task force to coordinate properly the medical service of all components. The medical plan must be issued in ample time to permit the formulation of plans by all medical elements of the task force and thorough indoctrination in those plans. The task force medical plan includes the organization of the task force medical service and the evacuation policy for the operation.

b. *Overseas Movement.*—During this phase, medical service to all embarked personnel is the responsibility of the task force medical service. Such assistance as is required is provided by the landing force medical service but all medical supplies are provided by the task force.

c. *Landing Operation.*—(1) *Battalion Phase.*—During the early part of this phase of the operation no effective control can be exercised over the flow of casualties to ships. Casualties occurring in landing craft are returned to ships. Casualties occurring ashore which require hospitalization of any degree are evacuated to landing craft, after troops have been debarked, and returned to ships.

(2) *Regimental Phase.*—As soon as the tactical situation permits, which is usually during this phase, measures are instituted to establish more effective control of the flow of casualties from shore evacuation stations to seaward. A tank landing ship, specially organized and equipped for casualty evacuation purposes, takes station off each assault regimental combat team beach. When this occurs, shore evacuation stations are relieved of their duties of controlling the seaward evacuation of casualties. Every casualty-carrying landing craft leaving the beach is directed by the beach party to the casualty evacuation control vessel off that beach. Here they are further directed, in accordance with medical plans and current instructions, to the various hospital ships. Casualty evacuation control plans call for certain types of casualties to be sent to certain specific ships in accordance with the medical facilities of the ship and the qualifications of the medical personnel. Changes in these plans are communicated to casualty evacuation control vessels by radio as the need for change arises. Records are kept by medical personnel on casualty-control vessels of casualties processed by them. All ships receiving casualties must insure proper litter, blanket, and splint exchange with the landing force medical service by immediately sending back to the beach in landing craft an amount of this equipment equal to that received from ashore.

(3) *Division and Corps Phase.*—After division clearing facilities of the landing force are established ashore, the need for casualty evacuation control vessels no longer exists and they may be relieved. Evacuation of casualties from ashore is at designated times and over designated beaches by landing craft as arranged between landing force surgeons and the task force medical officer, or their representatives. Conditions permitting, tank landing ships may be used as ambulance ships in evacuating

casualties from ashore. As hospital ships of the task force reach their casualty-carrying capacity they are dispatched from the combat area to advanced bases where they evacuate casualties to fleet and base hospitals. Before departing the combat area ships return ashore all casualties aboard who are fit for duty. Dead are normally sent ashore for burial.

(4) *Air Evacuation.*—When airfields or seaplane landing areas are available, air evacuation units at advanced bases are informed by the task force commander when to institute air evacuation. Air evacuation is under control of the task force commander who establishes the air evacuation policy through the task force medical officer in the medical plan. The landing force medical service delivers casualties to air evacuation units at aircraft landing areas in numbers and at times designated by the task force surgeon. A flight medical section from the air evacuation unit is established in the vicinity of the aircraft landing area. Casualties designated for air evacuation are received by this unit and processed to determine suitability of each casualty for air evacuation. (For further details on operation of casualty evacuation aircraft, see PHIB-12, "Amphibious Operations—Air Support.")

COMBAT CASUALTY REPORTING

Accurate casualty reporting in the landing force is dependent upon accurate reporting within divisions. During the landing and assault phase of an operation, prior to establishment ashore of division clearing facilities, the reporting of casualties within divisions is greatly handicapped by the lack of medical administrative personnel, time, the lack of health records and office equipment, and the necessary early evacuation of casualties prior to the establishment ashore of adequate record-keeping facilities. These difficulties can be overcome by thorough indoctrination and training of medical personnel of all echelons of divisions in proper methods of casualty recording and reporting. Higher echelons are not subject to these difficulties as adequate facilities, personnel, and time are available to permit the making of complete reports.

Forms and Reports.—Various forms must be kept and reports submitted by medical personnel and units who treat the casualty. The forms and reports listed below must be carefully compiled in order to facilitate the care of the wounded and the proper dissemination of information to units concerned.

a. *Identification (dog) Tags.*—These tags are an important factor in casualty identification and recording. Insuring that these tags are stamped with the required information is a responsibility of the medical service. Each individual of a combat unit should be supplied with two. Information on tags should include full name (no initials), serial number, date of last tetanus inoculation, blood group, and religion (P, C, or H.)

b. *Emergency Medical Tag.*—This is a standard navy medical form. It is prepared in accordance with instructions issued by the Bureau of Medicine and Surgery. Tags are made up in book form, the original being made out and attached to the casualty while the duplicate remains in the book. Completed books containing duplicate tags, and original tags which have been detached from casualties are forwarded through channels to the division medical record section for information and disposition. All medical personnel must be thoroughly trained in the preparation and use of this form so that they may make proper use of it under the most adverse field conditions.

c. *Casualty Information Card.*—These cards are prepared for each individual in the landing forces

UNDER EMERGENCY CONDITIONS

NAME _____ RANK _____ R-Rs

SERIAL _____ REL _____ ORG _____

NAME & ADDRESS OF NEXT OF KIN:

WND. G. S 2576 _____ COM. FAT. 2170 _____

WND. FRAG. 2584 _____ PSYCHO. WAR 1537 _____

BL. CONC. 2586 _____ INJ. TY. N. KN. 2599 _____

WNDS. MULT. 2564 _____ K. I. A. 2545 _____

OTHER _____ PROG ' Fav-Ser-Crt-Fat kl _____

A _____ DISP _____ IF EVAC: AIR / WATER / OTHER

INFO SOURCE _____

(OVER)

Figure 8.—Front of casualty information card.

UNDER NORMAL CONDITIONS

ID. Tag Issued _____ Bl. Type _____ Tet _____

A-RA-ACD _____ T-D-DD _____ MISCOND. _____

DIAGNOSIS _____ KL _____

FINAL DISPOSITION _____

(IF DISCHARGED DEAD)

BURIED _____ PL. _____ ROW _____ GRAVE _____

BURIED AT SEA: LAT. _____ LONG. _____ SHIP _____

DATE: OF DEATH _____ OF BURIAL _____

Figure 9.—Reverse of casualty information card.

Period Ending 2400: _____ (Date)

FIELD CASUALTY REPORT

_____ Reporting Unit

Name	Rate	Ser. No.	Unit	Diagnosis	Prognosis	Disposition

Figure 10.—Field casualty report.

Period Ending 2400:

Recapitulation and Bed Report.

Unit:

	Wounds			Sick			Nonbat Injuries			Gas Injuries			Comb. Fatigue			War Neurosis		
Classes	Adm	D *	Rem	Adm	D	Rem	Adm	D	Rem	Adm	D	Rem	Adm	D	Rem	Adm	D	Rem
Red																		
Blue																		
White																		
Total																		

* D = Disposed of.

Dispositions

	Red		Blue		White	
Air	Evac	Rem *	Evac	Rem	Evac	Rem
Water						
Other						
Total						

* Remaining to be evacuated

Beds Occupied

Beds Available

Total Bed Capacity

Remaining

Admitted

Evacuated

To duty

Died

Remaining

Red cases—Require over 30 days Treatment

Blue " — " " 15 " "

White " — " 5 to 15 " "

The above classifications vary with the situation

Figure 11.—Recapitulation and bed report.

by the medical section having custody of his health record. They are maintained by medical sections until immediately prior to embarkation for combat when they are delivered to the division medical record section, or to the record section of the corps medical battalion in the case of corps troops.

d. *Field Casualty Log.*—This is a ledger-type blank book kept by units operating medical installations for immediate recording of information about casualties passing through the installation.

e. *Field Casualty Report.*—This report is an abstract of field casualty log entries covering a 24-hour period. It is prepared and submitted daily by all medical units operating installations receiving casualties. (See figure 10, page 28.)

f. *Recapitulation and Bed Report.*—This is a report on casualties retained in clearing stations or hospitals. The report covers a 24-hour period and is submitted daily. It shows the relation between patients on hand and bed capacity of the installation. (See figure 11, page 28.)

g. *Report of Evacuations.*—This is a report submitted by all division or corps medical units operating installations which evacuate casualties from the division or corps. The report covers a 24-hour period and is submitted daily (see figure 12).

Functioning of Casualty Reporting in the Division.—a. *Forward Administrative Installations.*—(1) *Company Aid Men.*—Hospital corpsmen with assault companies are the first source of medical service information on casualties. After applying first aid treatment, these men tag casualties with the emergency medical tag. When they have expended all original tags in their books they turn in the books, containing the duplicate tags, to the battalion aid station. Careful preparation of the emergency medical tag by these personnel is essential. This is particularly so in cases where the casualty may be evacuated directly from the division after treatment by the company aid man, such as to landing craft on a nearby beach.

(2) *Battalion Medical Section.*—All casualties leaving the battalion area normally flow through the battalion aid station. Several men should be trained in record procedures, one of whom should have the primary duty of checking emergency medical tags of casualties received, adding more information to the tags or preparing new tags, making entries in the field casualty log, and keeping the battalion S-1 informed on the status of casualties in the battalion or battalion landing team. Field casualty reports and, in such cases where evacuation may be from the division by battalion medical personnel, evacuation reports are submitted to the regimental surgeon.

(3) *Regimental Medical Section.*—This section is responsible for recording and reporting only those casualties evacuated through, or treated by, regimental aid station personnel. The regimental chief pharmacist's mate, or other competent hospital corpsman, is charged with the duty of checking emergency medical tags, and making entries in the field casualty log. He checks field casualty reports and keeps the regimental S-1 informed of the status of casualties in the regiment or regimental combat team. Field casualty reports, and evacuation reports, if any, from battalions are forwarded together with similar reports from the regimental aid station by the regimental surgeon to the division medical record section.

b. *Rear Administrative Installations.*—(1) *Shore Evacuation Company.*—Since the shore evacuation station is the last source of information on casualties leaving the division in the early phases of an operation, it is essential that a complete and legible emergency medical tag be attached to each casualty evacuated, and that a complete entry be made in the field casualty log in each case. Field casualty and evacuation reports are prepared by shore party team shore evacuation stations and submitted to shore party group medical officers when they assume control ashore. Consolidated records are submitted to the division medical record section prior to dissolution of shore evacuation stations, or at the end of each 24-hour period.

c. *Collecting and Clearing Companies.*—Since cas-

Report of Evacuations.

Period Ending 1600 (Date) Reporting Unit.

	Evacuated			Remaining		
	Officers	Enlisted	Total	Officers	Enlisted	Total
By Air						
By Water						
To Supporting Med Units						
Total						

Phone to Record Section prior to 1700 daily.
Forward report via Message Center.

Figure 12.—Report of evacuation.

ualties are normally evacuated from divisions by these companies, keeping of records is an important function and personnel are thoroughly indoctrinated in standard procedures of recording and reporting casualties. Emergency medical tags must be complete and properly attached to casualties when they are evacuated from the clearing station. If casualties are retained under treatment, bedside charts should be maintained, if practicable. Complete information of treatment or surgery should be entered in the field casualty log or on file cards in order that health record entries may be made after return from the combat area. Reports, which are forwarded to the division medical record section, are the field casualty report, recapitulation and bed report, and evacuation report. When, practicable, a typewritten report of admissions and dispositions should be submitted in lieu of the field casualty report.

(3) *Division Hospital.*—Record keeping and reports of this installation parallel those of collecting and clearing companies. Since evacuation of casualties from the division is not a normal function of this installation, evacuation reports will be infrequent. When more than one hospital company makes up this installation, a consolidated section for records and reports should be established. Reports are submitted to the division medical record section which is located at the division hospital.

(4) *Division Medical Record Section.*—The duties of this section are as follows:

(a) Receive all medical reports from medical units of the division.

(b) Check field casualty reports received and enter information from them on individual casualty information cards.

(c) File casualty information cards.

(d) Submit daily a consolidated numerical report of evacuations from the division to the division surgeon, and G-1. The division surgeon submits the report to the corps surgeon. Copies of the report are distributed to all echelons of the division.

(e) Consolidate admission and disposition reports from all collecting and clearing companies. The consolidated report is submitted to the division surgeon. A report is forwarded to the corps surgeon and distribution is made to all echelons of the division at frequent intervals.

(f) Consolidate evacuation reports, listing names, organizations, and disposition of all casualties evacuated from the division, except those reported in (5) under the general headings of "Wounded and Evacuated" and "Sick and Evacuated." The report is submitted to the division surgeon and G-1. The division surgeon forwards the reports to the corps surgeon.

(g) Consolidate recapitulation and bed reports and submit to the division surgeon. The division surgeon submits the report to the corps surgeon.

(h) Consolidate reports of casualties for submission to the Bureau of Medicine and Surgery and submit to the division surgeon.

(i) Terminate health records of the dead and prepare reports of death with the assistance of the graves registration section.

(j) Maintain liaison with medical installations of higher echelons receiving casualties from the division to insure accurate information on casualties leaving the division.

Functioning of Casualty Reporting in the Corps.—a. *Medical Sections of Corps Troops.*—Aid stations of these battalions maintain the same records and make the same reports as battalion aid stations of divisions. Reports are submitted to the headquarters and service company of the corps medical battalion.

b. *Medical Companies.*—Such of these units as are operating hospital installations for corps troops maintain records and submit reports as prescribed for division collecting and clearing companies. Reports are submitted to the corps surgeon's office.

c. *Corps Evacuation Hospital.*—Records and reports of this unit correspond to those of division collecting and clearing companies and are submitted to the corps surgeon's office.

d. *Medical Section of Corps Special Staff.*—The corps surgeon is the evacuation officer of the corps. Medical reports from all medical units of the corps are consolidated in his office. He reports daily to the landing force surgeon, or to the task force medical officer if the corps surgeon is also landing force surgeon, the number of casualties evacuated from the corps. If the corps surgeon is also landing force surgeon he submits detailed casualty reports to headquarters Fleet Marine Force.

AIR EVACUATION FROM OVERSEA BASES

Transportation of the Sick and Wounded.—Generally speaking there are three major methods of transportation available for evacuation of casualties on a large scale from an oversea theater of operations: air, water and rail.

Advantages of Evacuation by Air.—The removal of patients by air from theaters or bases greatly reduces the quantity of medical supplies, hospital equipment, food, and other class I supplies, and the number of medical and nonmedical personnel that it is otherwise necessary to transport to the theater or base. From 250 to 650 patients, depending upon the type of transport airplane employed, can be removed in less than 48 hours to the zone of the interior from a theater 3,500 miles away by the use of 20 transport airplanes. Yet, to hospitalize this number of patients requires several trainloads or shiploads of equipment initially, and many tons of all classes of supplies each week for the care and maintenance of patients and medical personnel, as well as additional requirements of a large number of Medical Department officers, nurses, and enlisted men.

Strategic Value.—The strategic importance of air evacuation must be borne in mind by all theater and task force commanders, and by all officers concerned with the preparation of plans for military operations.

Speed.—The attainable speed of air transport will decrease evacuation time and reduce the number of fatalities incident to transportation, providing that, under medical supervision, cases for evacuation are properly selected prior to, and properly cared for during, the actual movement.

Comfort of Patients.—In general, no other mode of transport approaches the degree of comfort offered the patient by the airplane. The discomfort, and actual danger involved in certain types of cases, may be circumvented by low-altitude flying or by the administration of oxygen en route.

Safety.—The airplane, if air superiority is maintained, represents the safest means of transport and, if cases for movement be selected properly, the safest method of transportation.

Morale.—The morale of the entire fighting force is markedly elevated by the knowledge that wounded can be removed within a matter of a few hours, rather than days, to a hospital where excellent medical facilities are available.

Treatment En Route.—In aircraft converted for transportation of casualties, considerable treatment can be administered en route. Examples: readjustment of splints; administration of stimulants, sedatives, plasma, and other medication; arrest of hemorrhage; treatment of shock; and most important of all, administration of oxygen, when indicated. All aircraft intended for purposes of evacuation should be equipped with apparatus for the administration of oxygen.

Medical Supplies.—Aircraft utilized for evacuation are employed, in their forward movement, for delivery of supplies, including medical supplies, to units functioning in the combat zone

Redistribution of the Medical Task.—Institution of evacuation by air within the combat zone will transfer the heavier treatment load from mobile installations of the combat zone to fixed installations of the communications zone or zone of the interior.

Evacuation, Where Otherwise Impossible.—Casualties are evacuated by air from islands, isolated and other inaccessible localities, and across water, from which land or sea transportation is inadequate or impossible.

WATER TRANSPORTATION

For transportation of the sick or wounded by water, any floating conveyance, depending upon its availability and feasibility, may be used.

Hospital Ships.—Hospital ships are used only to transport sick and wounded patients. They must conform to the following provisions of the Hague and Geneva conventions to enjoy immunity from attack:

1. The painting will be distinctive, and in conformity with current international agreement.

2. The Red Cross flag will be flown.

3. The vessel will be announced to the enemy prior to its employment.

4. It will be manned and staffed by noncombatant personnel.

5. It will not be employed for any military or

unneutral purpose such as the transportation of armed forces, military supplies, or military communications.

Personnel and Facilities.—The hospital ship is staffed by a hospital ship complement. This unit provides the medical service of the ship, and corresponds roughly to the staff of a station hospital. The ship itself may operate as a hospital, providing definitive treatment during the early stages of landing operations, or it may act as an ambulance ship transporting patients from the theater of operations to the zone of the interior.

The hospital ship will have all the medical facilities of a well-equipped hospital, including wards, operating rooms, X-ray room, pharmacy and laboratory and complete dental facilities. Full details describing the naval hospital ship can be found in the Orientation Course under "Facilities of the Medical Department."

The APH's or Attack Transport Hospital was a development of World War II. These ships operate outside the Geneva conventions. They are camouflaged and heavily armed. Their employment doctrine is to deliver attack troops to the combat area and to evacuate casualties to the rear areas at high speed. With a top speed of 22 knots and a cruising speed of 18 knots, they are capable of operating without escorts. There were three ships of this class in operation at the end of the war; The *Tryon,* the *Rixey,* and the *Pinkney*. Facilities on this class of ships are available for a total of 1,150 patients with 300 beds reserved for major casualties. With two operating rooms on the second deck amidships and two auxiliary operating rooms forward and aft, this type of ship is capable of expeditiously handling combat casualties. The staff of the APH's consists of 12 medical officers and 60 hospital corpsmen. Equipped with the Higgins-type landing craft, the APH's are capable of actively participating in the evacuation of casualties from the beach.

The LSTH was also a World War II development. This consists of a standard LST with augmented surgical facilities and medical personnel installed in some cases on the tank deck and, in others, within the organic living spaces. LSTH's with augmented medical facilities may be stationed close in to the shore party evacuation station of each regimental combat team. Their mission is to screen the flow of casualties to the various ships and to provide emergency surgery. Once the LSTH is on station, all landing craft leaving the beaches with casualties are required to report to the LSTH instead of to the logistic control ships.

LOADING SHIPS OR SMALL CRAFT

At Docks.—When the tactical situation permits, ships employed for water evacuation will be loaded at suitable ports. Since ports are natural targets of enemy aerial bombardment, ships must be loaded and cleared as rapidly as possible. Patients are carried aboard ship from ambulances by litter squads, or may be loaded by Stokes litter or loading box and the ship's hoist.

Offshore.—Often, especially in the initial phases of a landing operation, there will be no port facilities available for the loading of evacuation ships. In such circumstances hospital ships will approach as close to shore as possible, where they will be loaded. Any type of landing craft may be used to transport patients from the shore to the ship. Since landing craft carry combat troops and materiel on their shoreward trips, they are objects of hostile attack. Therefore when used for patient evacuation they must be loaded and en route with all possible speed. Patients may be placed flat on the decks of the craft or litter racks may be improvised. Small craft will be loaded by hand, while some sort of loading box will facilitate greatly the loading of larger craft. After small landing craft have made their voyage from shore to ship, litter patients can best be transferred to the ship by means of loading boxes or Stokes litters.

RAIL TRANSPORTATION

Rail transportation from a naval medical-service standpoint is limited in scope. Railroads are utilized for transportation of the sick and wounded from ports of debarkation to naval hospitals specializing in the treatment of the specific type of casualty from which patients suffer. For example: Neuropsychiatric, amputations, plastic surgery, etc.

Casualties evacuated from ports of debarkation are, as a rule, sent to the naval hospital closest to their homes.

In the case of a large number of casualties being evacuated the utilization of a standard or nonstandard hospital train is recommended.

Standard Pullman sleepers are readily convertible to hospital trains. Each car is capable of transporting from 20 to 24 patients, including 10 to 12 litter cases. Litter cases should be placed in lower berths only, except in cases of emergency, as placing them in upper berths not only presents great difficulties in loading but also makes treatment en route more difficult. Sleeper berths may be used or hospital beds installed. Compartments for quartering duty nurses are also available.

One standard baggage car for each improvised hospital train is required for the purpose of transporting baggage and equipment of patients and duty personnel, and surplus medical and other supplies.

One or more standard kitchen cars should be provided when a trip of considerable distance is contemplated. One divided into a kitchen and dining room is preferable. Patients are fed on trays in the modified ward cars.

Both the Army and Navy developed a standard hospital train during World War II consisting of the following equipment:

1. *Sixteen Ward Cars.*—Each ward car has eight double bunks, thus accommodating 16 bed patients. In the center of the car are two seats on which ambulant patients and ward personnel can sit. Equipment includes a toilet, bedpan washer, and medicine chest.

2. *One Utility Car.*—The utility car has two large electric generators, two large steam generators, storage lockers, showers, and other facilities.

3. *One Officer Personnel Car.*—This car is divided into two sections. At one end are two double bunks for four officers, at the other there are three double bunks for six nurses. Separate latrines and shower facilities are in the center.

4. *Two Orderly Cars.*—Each of these two cars contain bunks, latrines, and shower facilities for 16 hospital corpsmen.

5. *Kitchen, Dining, and Pharmacy Car.*—This car is divided into three sections. At one end are kitchen and food storage facilities for preparation of food for patients and hospital train personnel. In the center are tables for 16 diners. At the other end is a small pharmacy with sink, shelves, and cabinets.

When such hospital trains are available it represents the ideal in transportation for the sick and wounded.

DISPOSITION OF THE DEAD

Ashore.—The remains of all dead on assault beaches will be retained ashore for identification, recording, and burial by the graves registration service of the landing force.

Afloat.—The remains of all dead afloat will, if practicable, be sent ashore. When conditions do not permit transfer ashore, remains will be properly identified, recorded, and buried at sea.

Burial.—Burial of the dead is not a medical responsibility.

TRAINING

Medical training in an amphibious task force is divided into three general classes in accordance with the personnel to whom the training is given. These are as follows:

1. Training of medical personnel.

2. Training of nonmedical personnel assigned specific medical service duties.

3. Training of all nonmedical personnel.

Military training, to include individual protective measures and use of weapons, if authorized, is given all medical personnel serving with the landing force.

All medical training is given under the supervision of appropriate medical officers. Military training of medical personnel is conducted in conjunction with similar training given military personnel.

MEDICAL PERSONNEL

Task Force.—All medical personnel of the task force receive uniform basic medical training to include advanced first aid and casualty handling.

Specialized training is given in the particular duties assigned individuals including use of pertinent medical facilities.

Any medical personnel assigned to beach parties are given military training in individual protective

measures. If they are to be armed, they are given training in the care and use of assigned weapons. This training should be under supervision of beachmasters.

Landing Force.—Basic medical training, as for task force personnel, is given all medical personnel of the landing force.

Specialized training is given individuals in their assigned duties. Within-divisions training is under the general direction and supervision of the division surgeon and is carried out in detail by regimental and battalion surgeons. Special attention should be given to thorough indoctrination in medical standing-operating procedure, with emphasis on casualty reporting.

All personnel must be thoroughly trained, concurrently with similar training of line personnel, in individual protective measures, care and use of individual weapons, if prescribed, and defensive tactics in the protection of medical installations, particularly against enemy infiltration attacks.

Medical units must be thoroughly trained in the combat operation duties of the unit. Training should parallel that of combat units so that medical units are prepared to take part in field exercises with combat units during shore-based training, and to participate effectively in joint training exercises. While training in duties relating purely to the practice of medicine and surgery is essential, it must not be at the expense of training in embarkation, ship-to-shore movement, and field operating technique under combat conditions. Training programs for medical units must be well balanced and must allot adequate training time to all subjects in which proficiency is required for efficient combat functioning.

NONMEDICAL PERSONNEL ASSIGNED MEDICAL SERVICE DUTIES

Task Force.—This type personnel includes, particularly, crews of landing craft, and personnel aboard transports required to handle casualties.

Crews of landing craft must be given special training in casualty handling to include first aid, the use of casualty handling equipment, and standing operating procedure for shore-to-ship casualty evacuation control.

Deck force personnel aboard ships equipped to receive casualties must be trained in methods of loading casualties on ships from landing craft, and the transportation of casualties by litter and other means aboard ship.

Landing Force.—The use of nonmedical personnel in the landing force is usually confined to the duties of litter bearers. Personnel to be made available for this duty should be determined prior to an operation and special training given them in the technique of litter bearing and other casualty handling methods.

All Personnel.—Training of this class is uniform throughout all units of both the task force and landing force and should include the following:

1. Casualty handling.
2. Use of morphine syrette.
3. First aid treatment of the injured, including handling of fracture cases, bandaging and applying battle dressings, treatment of burns, and emergency control of hemorrhage.
4. Resuscitation of the apparently drowned.
5. Personal decontamination where chemical agents are used.

CHAPTER 2

THE MEDICAL ASPECTS OF AMPHIBIOUS OPERATIONS IN THE PACIFIC*

The following subject matter consists of a compilation of timely articles or of excerpts from such articles prepared by those who are directly or immediately engaged in duties in the fields covered. They may be accepted as the best available information at the present time.

GENERAL CONSIDERATIONS

An amphibious operation may be defined as an attack launched from the sea for the purpose of seizing a hostile shore. The value of this simple definition for such a complex procedure lies in the fact that it does not attempt to delineate the various elements that go to make up an amphibious force, but rather infers the joint action of all Army, Navy, Marine, and Air forces. This same line of thought must be taken when we consider the medical aspects of such an operation. True, there are various phases and spheres of action where the responsibility for the medical service shifts from one group to another, but the mission of the medical forces, to keep men fit to fight and to care for those unable to do so, is the same for all elements.

Amphibious operations are considered to be the most difficult of all military engagements, demanding intricate planning and timing if they are to succeed. Every operation has its own peculiarities such as the beach conditions, terrain inland from the beaches, the strength of the enemy forces, our own ability to control the air and sea, the distance of the assault from our bases, and many other variables. However, a basic pattern has been developed for such operation and upon it the plan for the attack on any given target is predicated. Such a pattern is called "standing operating procedure." The Medical Department, no less than other elements, has a standing operating procedure. It is the purpose of this text to describe that procedure in detail. Unfortunately, there is no teacher like experience, but the medical officer who, through study, has acquired an understanding of the basic factors involved, and the responsibilities and capabilities of the various echelons of the medical service, will undoubtedly be able to make more of his medical talents than the individual to whom all is confusion. It is said that all war is confusion, but that success in an amphibious operation depends on having *organized* confusion.

Before going into a technical discussion of the medical service, it might be well to point out to the medical officer just what may be expected of him in exercising his professional abilities while serving with the amphibious forces in an engagement. While it is true that rapid evacuation is the guiding principle in handling casualties, the fact that amphibious operations are usually undertaken at some distance from an established base means that all life-saving definitive care must be administered right at the objective area. A few figures from some of the more severe operations in the Pacific will indicate the enormous casualty burden placed upon the medical service: Tarawa, 3,074 in 62 hours; Saipan, 16,000 in 26 days; Palau, 7,618 in 20 days; and Iwo Jima, 19,000 in 21 days. It is only necessary to consider the impact that 100 traumatic cases would have on the average well-

* As prepared by Captain E. R. Herring (MC) USN.

established hospital to realize the training, planning, personnel, and facilities that are needed to successfully handle casualty loads of the above magnitude. Accurate statistics are difficult to maintain under battle conditions, but on a particular operation, available figures show that one division medical battalion admitted an average of 250 patients a day for 20 days in a row. The orthopedic surgeon with this battalion operated on, or directed the care of, no less than 266 compound fractures, and the eye surgeon did 116 operative procedures in his specialty. The immense problem of prevention and treatment of shock is demonstrated by the fact that on Okinawa alone, over 40,000 pints of whole blood, 3 days removed from donors in the United States, was administered, in addition to uncounted thousands of units of other blood substitutes.

What does it take to provide medical care for casualties of this magnitude? First, the best medical talent that can be obtained. Without it, the seriously wounded would not live to reach established medical installations at rear bases. The casualty's chance for survival often depends on the skill of the first medical officer with whom he comes in contact. Battle is no place for the untrained doctor to learn his profession, unless he is under the immediate guidance and supervision of top-flight men. Second, medical officers with an appreciation of their mission, and the knowledge of how they are going to accomplish that mission. Third, a sound medical plan, based on all known factors that can affect the number of casualties, and the method of handling these casualties. Such a plan is derived from the medical estimate of the situation as integrated with the military tactical plan, and provides for adequate medical facilities based on the expected casualties. Fourth, enlisted medical personnel, who have been trained by their medical officers into competent and smooth-working medical units.

One other factor might be well worth mentioning. There is no substitute for forethought and careful planning, but no amphibious operation is ever carried out exactly as planned. As a matter of fact, the success of the operation often depends on the ability of the alert commander to take advantage—extempore—of the situation as he finds it. This is also true of the medical service, particularly ashore. This ability to improvise, to "make do," cannot be overemphasized. At best, the conditions under which the medical officer must work in battle can but approximate the facilities with which he has been trained to work in civilian life, with the possible exception of the hospital ships. To fail to make the best of every situation is a breach of faith with the men carrying the attack.

It would be futile to attempt to propound the medical service of an amphibious operation without some discussion of the organization and methods of the naval and military forces involved. While the medical officer occupies himself mainly with the care of casualties, he must in many instances assume some of the aspects of the military leader in planning and executing his mission, and in the handling of his men and organization. Further, from a purely personal standpoint, he is as interested as any other individual in the development, progress, and ultimate outcome of the engagement. The composition of the forces engaged in an amphibious operation and the normal sequence of events will therefore be outlined, and, prior to discussing the separate medical services of the attack and landing force, the organization of each element will be gone into in greater detail. The final chapter in this subject will be a narrative account of the Medical Department's role in a typical amphibious operation in the past war in the Pacific. It is hoped that this "case history" will further emphasize to the reader the responsibilities and opportunities of those who participate.

JOINT OPERATIONS

An amphibious operation is a joint operation in its fullest sense. Navy, Army, Air and Marine forces act together under the leadership of an over-all commander. Mutual cooperation is the essence of a successful attack. Throughout the staffs of all major elements, officers of the various branches work side-by-side to coordinate the activities of all forces. Since so much depends on the naval elements involved in controlling the sea and supporting the operations logistically, the over-all command usually rests with a naval officer. However, if the amphibious phase is merely the prelude to a large-scale land offensive, such as the Normandy invasion, command is placed in the hands of an Army officer.

To forestall any misunderstanding, a *joint* operation differs from a *combined* operation in that

the term "combined operation" indicates the participation of the forces of foreign-power allies.

Joint Expeditionary Force.—The over-all tactical organization that is involved in amphibious operations is the *Joint Expeditionary Force.* This force consists of the expeditionary troops, which are to make the landing; the assault shipping and aircraft required to transport the troops to the objective and land them; and the naval and aircraft forces necessary to protect the various elements of the force while en route to and at the objective, to prepare the objective for landing, and to support the troops during and subsequent to the landing.

There are, of course, other forces, such as the submarine forces, naval striking and covering forces, logistic support forces, long-range air reconnaissance forces, and the strategical bombing forces, which are employed prior to and during such an operation, but these forces are not strictly a part of the Joint Expeditionary Force.

For an understanding of the medical picture, it is sufficient to divide the Joint Expeditionary Force into three major groups:

1. *The Attack Force.*—This force consists of the assault transports and similar amphibious-type vessels, which are used for transporting the expeditionary troops and are of medical importance because of the facilities they provide for the treatment and evacuation of casualties. If the operation is of large magnitude, or the assault is to be made in two or more landing areas, there may be two or more attack forces within the Joint Expeditionary Force.

2. *The Expeditionary Troops or Landing Force.*—The term "landing force" is applied to the amphibious troops who are to make the landing and may include such garrison troops and base development units as are required during the assault.

3. *The Support Forces.*—These elements of the force, although under separate commands, are grouped under the heading of "support forces" for purposes of easier understanding. They have their own organic medical service and do not usually play a role in the evacuation of casualties. On the other hand, the amphibious-type vessels of the attack force are called upon to evacuate casualties from this force in the event of major casualties. They contain such forces as:

a. *The Advance Force,* which precedes the main body of the Joint Expeditionary Force to the objective. Its main task is to prepare the objective for assault by conducting the necessary mine-sweeping, reconnaissance, preliminary gunfire, air bombardment, and underwater demolition operations.

b. *The Tactical Air Control Group,* which exercises over-all control of all aircraft operating in the objective area.

c. *The Demonstration Group,* a force of sufficient size to make a show of force, with the purpose of creating the impression of an intended landing, and thus diverting the enemy from the actual landing beaches.

d. *A Reserve Group,* which carries reserve troops, capable of being formed into a landing force, if needed.

e. *The Carrier-Support Group,* to furnish air protection, antisubmarine screening, and air support to the shore operations.

f. *Land-Based Air Units,* which are committed as soon as landing fields are available on the objective, for the same purpose as the carrier aircraft.

g. *The Close-Covering Group,* which is a part of, or made up of elements of the aforementioned advance force, to provide a close-in screen for the vessels of the attack force.

PHASES OF AN AMPHIBIOUS OPERATION AND SEQUENCE OF EVENTS

For security reasons, detailed information as to the operating procedure of the various elements cannot be disclosed in an unclassified document. However, the broad concepts herein discussed will serve to give the reader a sufficient idea of the over-all pattern.

The phases enumerated below cannot be clear cut, and in many cases will overlap. The name of the phase merely indicates the principal event transpiring during that period of time. Many other major events will be transpiring concurrently.

First, Planning Phase.—During this period the plans for the expedition will be prepared and coordinated. Necessary reconnaissance by air and

submarine will be initiated early in this phase. The results of the planning at a high joint level will be distributed to the subordinate commands, who in turn make their detailed plans. During this time, pre-invasion operations, intended to neutralize the enemy's supporting bases and means of reinforcing the objective area, are carried out. Forces employed for this function include the naval striking forces and air elements, under the direction of higher authority than the Joint Expeditionary Force command.

Second, Embarkation and Rehearsal Phase.—The troops, vessels, equipment, and supplies which are needed for the particular operation, as decided during the planning phase, are assembled at places of embarkation. Actual combat loading of the landing force is carried out and rehearsal of the intended landing takes place, simulating as nearly as possible the conditions expected at the target area. Continued strikes and reconnaissance are being carried on during this phase.

Third, Movement to the Objective Phase.—As the title indicates, during this phase, the Joint Expeditionary Force makes a coordinated movement from the rehearsal or staging area to the objective.

Fourth, Landing and Assault Phase.—Actually, this phase includes certain prelanding operations, such as preliminary bombardment of the objective, especially the landing beaches, by naval gunfire and air. Mine-sweeping operations, beach reconnaissance, and underwater demolition operations off landing beaches are likewise carried out. The actual landing of assault troops, and the seizure of a beachhead of sufficient size to permit the building up of forces for further operations, is the event of major importance in this phase.

Fifth, Consolidation Phase.—In limited operations, such as small islands, the amphibious operation may be concluded before this phase is reached. However, against major opposition on large land masses, it is necessary during this phase to build up troops units and supplies for the continued offensive operation.

MEDICAL PLANNING

Medical planning, as all other planning, must first be on a high joint level, with the major commands represented. We will discuss here just what a medical plan consists of, what factors affect the planning, who makes the plan, and how it is promulgated.

Once the objective of the assault has been decided upon, the surgeon of the Joint Expeditionary Force confers with the surgeons of the Attack Force, Landing Force, and Supporting Forces, and based on all intelligence information available, makes a medical estimate of the situation. At this level, three factors are of primary concern.

1. The casualty estimate.

2. The amount of medical service ashore, afloat, and on advanced bases necessary to handle the estimated casualty load.

3. Broad methods of employment of the medical service to most effectively handle the expected casualties.

Once the broad concepts of the plan are decided upon, subordinate medical officers make their plans, going into more detail as the plan affects their organization. For example, the attack force surgeon plans in detail the method by which casualties will be distributed among the various transports and supporting hospital ships in his force; the landing force surgeon confers with division surgeons and plans as to evacuation procedures ashore, etc. Actually, the medical plans written by all echelons are the responsibility of the commander of that echelon but it is the medical officer's task to prepare them for his approval and promulgation. The medical plans of all units are usually issued as an annex to the administrative order of the over-all operations order.

Let us consider the first factor in our medical planning, the estimate of casualties. This estimate is based on casualty rates in similar operations in the past, and is influenced by such factors as are peculiar to the coming objective.

Thus, for an amphibious operation against a major force on a large land mass, with the objective of mounting further large-scale land warfare operations, we may select for comparison an engagement such as the Normandy landing. When confronted with an island operation of some size, where the follow-up offensive will be made by the same troops as used in the landing, we may study the Okinawa or Guadalcanal campaigns. Small islands, where there is to be a sudden, short, violent offensive

with total destruction of the enemy, are illustrated by the Tarawa, Kwajalein, or Palau operations. Once a similar campaign is picked for study and comparison, the factors listed below are considered as to how they will further affect the casualty rate. It must be remembered that it is important not only to have the over-all expected casualty figure, but insofar as possible, the approximate phase of the landing operation during which these casualties will take place. Thus, at Okinawa, the initial landing produced few casualties for the first 18 days, and hospital elements were given time to become established ashore, relieving the naval facilities of much of the burden of early definitive care.

Factors which further affect the casualty rate are as follows:

a. *The relative training of opposing forces.* If the enemy is known to be composed of battle-seasoned troops, rather than a hastily gathered force of untrained units, it may be reasonably expected that the task will be more difficult and the casualties consequently increased.

b. *The type of beaches and off-shore approaches.* If beach obstacles, such as reefs, or steep exits from the beach are to be encountered, the landing will be delayed and the enemy will have more opportunity to concentrate fire on the landing beaches, with resultant increase in casualties.

c. *The amount of cover available* for protection of troops on their advance inland plays an important part in the casualty figure. This was illustrated at Iwo Jima, where our troops were forced to advance across almost barren terrain, with resultant high casualty rates.

d. *The climate* is especially to be considered if there is any deviation from the climate with which the troops are accustomed. In cold weather operations, frostbite and trench foot will add to the non-effectives, and in the tropics the heat-exhaustion cases will add to the casualty rate.

e. *The probable diseases* to be encountered are of utmost importance if the operation is to be of any length. An example of this is the Guadalcanal campaign, where our ineffective rate from malaria was many times that of the casualty rate inflicted by the Japanese.

The enemy's ability to make use of artillery concentrations on the beach is an important factor. If the landing is made against a relatively undeveloped and undefended beach, with a view to coming to grips with the enemy after becoming well established ashore, few initial casualties may be expected. If there are no undefended beaches and the attack must be made into the face of well-defended positions supported by artillery, preparation must be made for maximum casualties starting at H hour on D day.

Having arrived at a reasonable casualty estimate, plans for the facilities to handle them must be made. The first decision should be as to just what degree of definitive treatment must be provided at the objective area. As before stated, plans generally must be made to do practically all the life-saving surgery right at the target area. But there may be operations, such as the Normandy landing, where the casualties can be quickly evacuated to well-established hospitals or rear bases, capable of more efficiently handling this function. To do the type of surgery called for by the condition of these casualties takes surgeons and surgical facilities. Merely to plan on having so many beds available at the various phases of the landing operation is not sufficient. In fact, it was one of the glaring weaknesses in the war in the Pacific. Let us assume that there are to be 1,000 casualties the first day. For planning purposes, we can assume that 20 percent, or 200, will be killed outright, or be beyond medical aid; 40 percent will be minor wounded, or have wounds which will be of such nature that treatment can be deferred. This leaves another 40 percent, or 400 cases, that demand a certain amount of definitive treatment. These are the cases we must plan for. As will be described later, under the medical facilities of the attack force vessels, we know approximately the rated capacity per day of the various ships. Assuming a fairly equitable distribution, and allowing for the loss of some of these vessels, simple arithmetic will tell us if we can handle the casualty load. If we cannot, then the normal medical complement of the ships charged with furnishing medical care must be augmented and additional ships, such as casualty carriers (APH), and hospital ships (AH), must be added to the amphibious task force.

The amount of medical service to be provided by field hospital elements ashore must be calculated. In a short, violent campaign on a small land mass, it will perhaps be impossible to establish any hospitalization ashore, and the personnel may be

utilized to augment the medical service afloat. On large land masses, however, the route of evacuation becomes lengthened and facilities for definitive care must be provided closer to the front lines by using shore-based hospital units. The capacity and utilization of these elements will be described under the medical service of the landing force.

A study of the airfield facilities that may become available on the target will indicate what can be expected from air evacuation and approximately the time that this means of evacuation will enter the picture.

Finally, while it is not necessarily the responsibility of the amphibious forces, in any full-scale operation the Joint Expeditionary Force surgeon should assure himself that hospital facilities of advanced bases that are in strategic support of the operation, are sufficient to receive and give adequate care to the casualties evacuated from the objective area.

The third point somewhat overlaps the second, in that the degree of definitive care that will be accomplished at the objective area influences the manner in which the casualties will be handled. Further, the method of distribution of casualties among the various medical facilities available must be decided; what casualties are to be evacuated during different phases of the operation, what casualties are to remain in the area; and of what use air evacuation will be to the medical service. *Regarding the distribution of casualties, it must be firmly understood that, except in situations where little or no resistance is to be expected at the initial landing, casualty distribution to ships afloat cannot be equitably carried out by any element functioning on the beach.* There must be some vessel utilized as a casualty evacuation control center, operating off each regimental beach, to insure an equitable distribution of the cases that demand prompt surgical intervention. Further, this vessel must be staffed and equipped so that it may actually give definitive care to casualties where further evacuation is contraindicated by the patient's condition, the interference of further evacuation during the hours of darkness, smoking for air alerts, or withdrawal of the transports. The LST lends itself admirably to this use and will be described in some detail later.

The decision as to what casualties will or will not be evacuated is stated in what is known as the *evacuation policy*. As may well be imagined, many casualties that reach the transports, especially during the initial stages, will have relatively minor wounds, and after brief care or rest, are again fit for duty before the transport is to sail from the objective area. Thus, if the operation is to be of fairly long duration, and the individual is fit for duty, he is returned to his outfit on the beach. This policy is expressed in days. For instance, in a 5-day evacuation policy, all those casualties that are expected to be fit for duty in 5 days or less are returned ashore when their condition permits, or transferred to ships remaining at the target area if the particular transport involved is to sail before that time. After the hospital elements are firmly established ashore, and the situation is somewhat stabilized, the evacuation policy is lengthened, as we then have sufficient facilities to take care of cases that will require more prolonged hospitalization. It must be understood that this evacuation policy is a guide only, as heavy casualties may revise it downward, with the object in mind of clearing all hospital elements for the reception of the new casualties.

Other factors covered in the medical plan are:

Medical Supply.—The over-all level of medical supplies to be carried by various elements of the force is stated in the Joint Expeditionary Force plan. Subordinate elements are then responsible for procuring these supplies from their normal logistic support sources, and arranging for their transportation to the objective area. Resupply of all elements for any period over the level stated in the logistic directive, is the responsibility of the commander, service force of the fleet. Such supplies are usually delivered in block shipments, based on the expenditure rate of supplies in past campaigns.

Preventive Medicine.—The plan will contain broad directives as to expected disease conditions and health hazards, and the responsibility of subordinate units in regard to preventive measures, such as immunization, airplane spraying of DDT, etc.

Instructions Regarding Handling of Prisoners of War Casualties and Casualties Among Civilian Personnel.—Prisoners of war are routinely evacuated through normal medical channels but, except in the early stages of the operation, are not taken to ships. Stockades are erected by military police in the

vicinity of hospital elements ashore and prisoners are held in these, or if their condition is serious, under special guard in the hospitals. Treatment of prisoners of war is carried out to the maximum extent, not, however, interfering with the care of our own wounded.

Casualties among civilians are the responsibility of the civilian affairs component, which is a separate organization attached to the landing force for this function. This organization contains its own medical service, which is set up especially for a particular operation, based on the known number of civilians on the target. Civilian casualties are evacuated along normal channels to stockades as far to the rear of the fighting as possible, and in some instances are taken to nearby islands in LST's to get them out of the combat zone.

Once the plan is written, the Joint Expeditionary Force surgeon must constantly keep himself informed of the readiness status of the subordinate units, to insure that they have the required personnel, equipment, and supplies to carry out their mission, and that proper plans have been made by these units to carry out their assigned responsibility in regard to casualty handling. Further detailed planning, as it is carried out by subordinate units, will be discussed under "Attack Force and Landing Force."

THE ATTACK FORCE

It would be unwise to confuse the reader with a detailed account of the command relationships of the various elements that make up the attack force during the various phases of the operation. Suffice to say that the landing force is considered an integral part of the attack force while en route to the target, and until the major portion of it is established ashore. Control then shifts to the landing force commander. On the other hand, the majority of the units which have been active in preparing the way for the assault, which have been designated the support force, come under control of the attack force once the attack force reaches the objective area.

From a medical standpoint, we shall be concerned only with those vessels and craft of the attack force which play a part in the care and evacuation of casualties. The same transports and landing ships, once they have disgorged their embarked troops, re-enforced by hospital ships and casualty carriers, furnish the medical service afloat to back up the landing.

These vessels may be divided into the following categories: transports, landing ships, landing craft hospital ships, and fast casualty carriers.

Transports.—APA.—Auxiliary, transport attack, 7,500-14,000 tons, 450-500 feet in length. These vessels are capable of carrying one complete infantry battalion to the objective area and are equipped with landing craft to land the personnel. There are three APA's to a division of transports, and three divisions to a squadron, one squadron usually making up the transport element of the attack force. The medical personnel of one of these ships normally comprises 2 medical officers, 1 dental officer, 1 hospital corps officer, and 12 hospital corpsmen. They are equipped with one complete surgical operating room, a minor surgery, and sick bay space of 24 bunks. Once the troops have disembarked, these ships have bed space for evacuation from the target area of 100 serious cases and 300 minor wounded. It will be seen immediately, that with the above medical complement adequate care cannot be given to this number of patients. Augmentation of the medical personnel, and planned distribution of casualties, limiting admissions to not more than eight major operative cases per day, is essential to successful operation of these ships as casualty-handling agencies. Augmentation through the APA's of the attack force must not only be in numbers, but should provide for the services of specialists in the handling of eye, brain, chest and psychiatric cases.

AP.—Auxiliary, transport, 7,500-18,000 tons, 450-600 feet in length. These ships are primarily troop carriers and should not be planned on to play a great role in the casualty-evacuation picture. They are equipped with a surgical operating room and, with augmentation of their normal medical complement, may evacuate 70 serious cases and 150 ambulatory cases.

AKA.—Auxiliary, cargo attack, 7,000-12,000 tons, 400-500 feet in length. These vessels are primarily designed to carry heavy cargo and have a limited casualty handling capacity. They have bed space for the evacuation of 15 serious cases and 50 ambulatory cases.

LSV.—Landing ship vehicle, 6,000 tons, 450 feet in length. These vessels, from their nomenclature,

may be confused with other landing ships. From a medical standpoint, they are listed under transports, however, to indicate their casualty carrying function and capacity. They are a newly developed type of transport, especially designed to carry amphibian tractors (LVT's) and amphibious trucks (DUKW's). They have the same medical personnel complement as the APA and are equipped with one complete surgery. Their bed capacity for evacuation from the target is slightly less than that of an APA.

Landing Ships.—These vessels are the landing ship tank (LST) and the slightly smaller landing ship medium (LSM). They were originally designed to carry vehicles and cargo right up to the beach and effect landing over a ramp through a large hatch in the bow. They now are used also for transporting the LVT's and troops that make up the first waves of the assault.

In itself, the LST has no part in the evacuation picture, but when a particular vessel of this type is utilized as a casualty evacuation control vessel, it assumes one of the most important roles in the entire evacuation picture. Vessels so utilized are augmented by from 4 to 10 medical officers and 25 to 40 hospital corpsmen. They are especially equipped with facilities for setting up surgical installations and facilities for the prevention and treatment of shock. They are equipped with a pontoon barge, which is lowered alongside to serve as a platform for unloading patients from landing craft. Ambulance boats, assigned from the transport squadron, facilitate the further evacuation of the casualties to the ships. Their function is as follows:

a. Assigned one in support of each regiment, they lie 1,500 yards off the assault beach and receive all casualties from the landing craft.

b. Those casualties which are in condition to be evacuated further are distributed to the transports and hospital ships, an equitable distribution being made both as to numbers and types of casualties, depending upon the ability of the ships to handle them.

c. If the patient's condition is such that further evacuation would endanger his chances of survival, he is held aboard the LST and such treatment as indicated is instituted.

d. In any situation where further evacuation is impossible, due to smoking of the transport area, during air alerts, during the hours of darkness, or in case of withdrawal of the transports, these ships must assume the full burden of casualty care.

e. In some instances where established hospitals are available within two days' run, these ships can be utilized to transport approximately 300 wounded.

The LSM may be utilized in a similar manner if LST's are not available. However, their evacuation capacity is much less and they do not have operating space to the extent provided by the LST.

Landing Craft.—These are the boats which are used to carry troops and cargo into the assault beaches and to carry casualties from the beaches in the seaward evacuation chain. There are many types, the most important of which are the following:

1. LVT.—Landing vehicle tracked. This is the familiar alligator or amphibian tractor. It is used especially where beach conditions preclude the use of ordinary boats, and may even be used some distance inland in carrying supplies and evacuating the wounded.

2. DUKW.—This is the amphibian truck which functions both on land and water, but inasmuch as it carries no armor or armament, it is not utilized in the initial assault. Later it is invaluable for transporting wounded directly from hospitals to casualty control ships, as their use obviates transfer from ambulance to landing craft at the beach.

3. LCVP.—Landing craft vehicle or personnel, 36 feet in length, with a 10-foot beam. This is the Higgins boat, and is utilized where beach conditions permit, to land troops and evacuate casualties.

4. LCM.—Landing craft medium, 50 feet in length, with a 14.5-foot beam. This is slightly larger than the LCVP and is used to land vehicles and tanks.

5. LCT.—Landing craft, tank, 120 feet in length and 32 feet in width. This is the largest of the landing craft. It is utilized for heavy equipment and is capable of landing five medium tanks.

As before stated, beach conditions dictate which of these craft will be utilized initially, and it may be necessary under certain conditions, to effect a transfer of the casualties from one type craft to

another. This is to be avoided if at all possible, however, and if the LST's are utilized properly as casualty control boats there are very few times when such a transfer should be necessary.

Hospital Ships.—AH. These vessels are the floating hospitals of the Navy, and can be compared, insofar as medical personnel and equipment are concerned, to an established 750-bed hospital. The average complement consists of 25 medical officers, 3 dental officers, 6 hospital corps officers, 250 hospital corpsmen and 30 nurses. Distribution of casualties should be such that the majority of cases of serious nature are assigned to these ships, not only because of their surgical facilities, but in view of the postoperative treatment facilities which they possess. These ships operate under the conditions of the Geneva Convention, are painted white with huge red crosses, and carry identifying lights at all times.

Fast Casualty Carriers.—APH. These are high speed casualty evacuation transports, especially constructed, equipped, and staffed for the prime purpose of making quick shuttle trips between the target area and rear bases. They have no distinguishing marks and depend on their speed for protection. The average medical staff consists of 10 medical officers, 2 dental officers, 2 hospital corps officers, and 51 hospital corpsmen, and they can evacuate 200 stretcher cases and 400 ambulatory cases. When augmented by additional surgeons, they can serve in the same capacity as a hospital ship, although to a more limited degree

STANDING OPERATING PROCEDURE FOR THE MEDICAL DEPARTMENT OF THE FORCES AFLOAT

This is the normal pattern of procedure upon which the medical plan is predicated. It serves as a guide in medical planning, and if the employment of the medical service is the same as outlined in this basic pattern, reference is made to this document in writing the medical plan for the sake of brevity. Essentially, it outlines the manner in which we would like to have the medical service operate. Standing operating procedure is abbreviated to SOP and this abbreviation will be used wherever the term is intended. There is an SOP for the basic employment of all elements.

The medical SOP for the attack forces details the normal casualty-handling capacity of various types of ships, the normal method of distribution of casualties from the beach to the ships, the responsibility for supply and the casualty reporting methods to be used.

Since we have discussed the casualty capacity of the various types vessels of the amphibious force, no repetition is necessary here. The method by which we attempt to secure an equitable distribution among the ships, which is the real key to success from a medical standpoint, will be discussed at some length.

The responsibility for casualty handling on the part of the attack force begins when casualties are transferred from the beach to the landing craft. In early operations, it was SOP for the ships to furnish a naval medical beach party to assist the landing force in the transfer of such patients over the beach to the landing craft and direct the distribution from that point. It was learned, however, that such distribution could not be accomplished due to the lack of communication and the general confusion existing on a "red-hot" beach in the initial stages of the landing. The LST's were brought into play for this distributing function and the attack force medical department now participates on the beach only to the extent of furnishing liaison medical officers to the shore party evacuation stations for advice as to the capabilities of the offshore evacuation facilities.

Once the casualties are in the landing craft, they are conveyed to the casualty control vessel lying usually 1,500 yards off the beach. It may be that this vessel is not on station as yet, due to the fact that they have other functions initially, in which case the landing craft transport the casualties to the various transports in accordance with prearranged plans. It is imperative that the casualty evacuation control boat get on station before large numbers of casualties are encountered, to insure equitable distribution. Experience has shown that the coxswains of the landing craft, on leaving the beach, regardless of instructions, are inclined to take their casualties to the nearest transport; thus, the ships lying closest to shore are overloaded while those farther out are left idle.

Once the casualties reach the casualty evacuation control vessels, sorting and triage take place. They are removed from the landing craft and those who are in immediate need of treatment for shock or hemorrhage are given such treatment at once.

SHIP CAPACITY FOR HANDLING CASES

Ship	Normal medical complement		Evacuation capacity of convalescents, sick, and minor injuries		Admission rate per day of untreated cases requiring major surgery
	M.O.	*H.C.*	*Bed*	*Ambulatory*	
APA	2	12	100	300	8
AKA	1	5	15	150	3
AP	2	12	70	150	6
LSV	2	12	70	150	6
APH	6	51	200	400	20
AH	25	253	350	200	50
LST	30 nurses (Must be computed individually based on degree of augmentation)				

Minor wounded are further evacuated by ambulance craft furnished by the transport squadron and distributed more or less indiscriminately to the transports.

Those that demand definitive surgical care are distributed to the transports, APH's or AH's, on the basis of the ability of the various vessels to handle these cases at that particular time. For instance, the record shows that a certain APA has just been sent three cases that demand immediate surgical intervention. Unless all the other vessels are likewise surfeited with these types of casualties, no more will be sent to that ship until it is reasonable to assume that she has cleared her surgery. The table above will show the average capacity of the various type ships for handling cases demanding immediate major surgical care.

As a rule, the most serious patients are sent to the hospital ships to the limit of their daily capacity, in view of the better facilities for postoperative care that are provided. Transports will receive their share, however, and must have every facility set up in readiness for triage, shock therapy, and surgery. The troop officers' wardroom is utilized for triage and shock treatment, with only the most serious being taken directly to the sick bay. Troop officer berth spaces are utilized for bunking serious cases and the remainder are carried in the troop berthing spaces.

Casualties are best unloaded from the landing craft by hoisting the craft to the rail of the transport if there are several litter cases aboard. Individual litter hoist, by means of a stretcher sling, may be accomplished if the sea is fairly calm. Hospital ships are equipped with an electric crane for individual lift of casualties.

When the casualty-carrying capacity of the ships is reached and the tactical situation permits, ships of the task force retire to designated advanced bases where casualties are transferred to established fleet or base hospitals. Prior to departure from the target area, all casualties that are fit for duty are transferred ashore, and those that will be fit for duty within the limits of the evacuation policy are transferred to other ships which are to remain longer in the area.

To recapitulate on the chain of evacuation afloat: liaison medical officers from the transport squadron advise initially on the beach as to the distribution of casualties in accordance with prearranged plans. When the casualty control boat takes station off each regimental beach, all boats carrying casualties return wounded to these vessels where they are removed from the craft, and triage and such treatment as is indicated is immediately carried out. Distribution by means of ambulance boats is accomplished, based on the known capacity of the various type vessels to receive casualties. Casualties fit for duty are returned to the beach before the vessels leave the transport area.

As can be seen, except for the first few hours, this is a fairly stabilized procedure and successful handling of casualties by the forces afloat depends mainly on two factors. One, adequately planned facilities afloat to take care of the estimated casualty load, including the services of specialists in the various surgical fields. Two, equitable distribution of serious casualties to the various ships to prevent overloading of surgical facilities at any given time.

Medical supply for the attack force is usually not a great problem, inasmuch as its situation is fairly stabilized. There are several points worth mentioning, however. The ship's medical department is responsible for furnishing all medical supplies and equipment utilized in caring for the expeditionary troops while they are on board en route to the

target, as well as those needed for the treatment of casualties received during the assault. In some cases they will be responsible for the transporting of whole blood for use on the beach, in addition to the whole blood they will need for the treatment of casualties received. Doctrine also states that the ships will return ashore a like number of litters, blankets, and splints as are received with the casualties. This is called "automatic exchange" and sufficient of these items should be kept available so that an immediate exchange can be made, rather than wait for the same items received with the casualties to be returned to the waiting landing craft.

Casualty Reporting.—Casualty records are of utmost importance, not only to keep the senior medical officer informed of his casualty-load status, but for the purpose of showing the eventual disposition of the patients. It can well be imagined that during the assault on a well-defended beach, no complete records can be kept ashore initially, and the ship's record of admissions and dispositions will be the only record available showing what happened to a particular individual. Each vessel, therefore, keeps a running log of admissions, with name, rank, serial number, organization, diagnosis and disposition. A consolidated report is made as soon as practicable after departure from the forward area, to the commander, amphibious force, giving the following additional information:

1. Name in full (surname first), rank, rating, serial or file number.
2. Type of casualty.

Battle casualty:

a. Killed in action.
b. Died as result of wounds received in action.
c. Died as result of injuries received in action.
d. Seriously wounded in action.
e. Seriously injured in action.
f. Slightly wounded in action (requires hospitalization).
g. Slightly injured in action (requires hospitalization).
h. Missing in action.
i. Seriously ill, gas casualties.

Non-battle casualty:

a. Conditions not result of enemy action.
b. Psychoneurosis or mental disease developing under battle conditions (commonly but improperly designated as battle neurosis, hysteria, shell shock, etc.).

3. Date and place of casualty.
4. Duty status.
5. Diagnosis—Navy nomenclature of disease and injuries.
6. Prognosis—fatal, probably fatal, serious, or favorable.
7. Flying status if known.
8. Source of admission—from ship, beach, etc.

The following distribution is made of this report by the commander, amphibious forces:

DISPOSITION OF REPORTS ON EVACUATED SICK AND WOUNDED

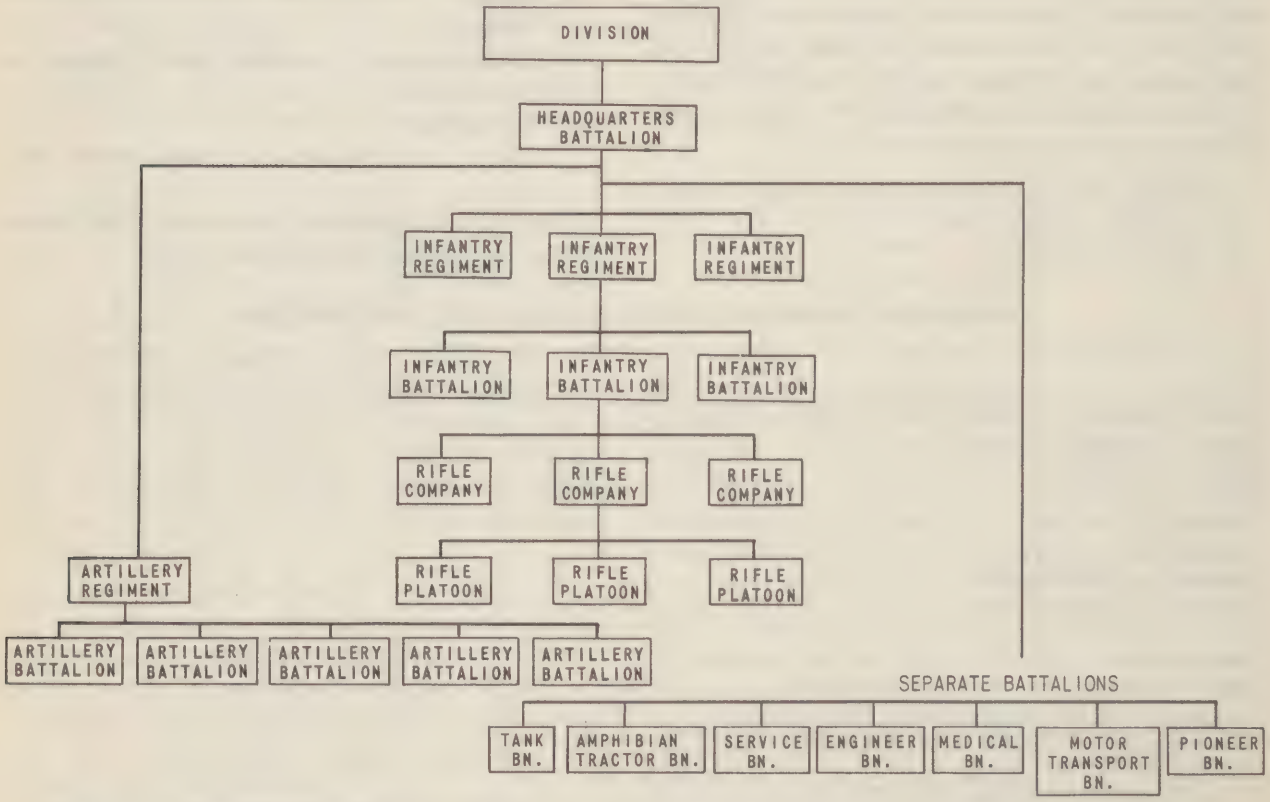
	Army	Navy	Marine	Coast Guard	Prisoners	Civ.
Adjutant General U. S. Army (Casualty Section) Wash. D. C.	* 2	.....	.....	.....	1	1
Surgeon General U. S. Army Wash. D. C.	1	.....	.....	.....	.....	.....
Chief of BuM&S	.....	1	1	1	1	1
Chief of NavPers	1	1	1	1	1	1
CominCh U. S. Fleet	.....	1	1	1	.....	.....
CinC (Fleet)	.....	1	1	1	.....	.....
Commander Attack Force	1	1	1	1	1	1
Commander Landing Force	1	1	1	1	1	1
Com. Gen. FMF	1	1	1	1	1	1
ComGen Area	1	.....	.....	.....	.....	.....
Army Receiving Officer Port of Debarkation	3	.....	.....	.....	.....	.....
Commandant, Coast Guard Hdqtrs. Wash. D. C.	.....	.....	.....	1	.....	.....
Commandant, U. S. Marine Corps, Wash. D. C.	.....	.....	1	.....	.....	.....
The Secretary of the Navy	.....	** 1	** 1	** 1	.....	.....
Commanding Officer of ship making the report	1	1	1	1	1	1

* One should be original.
** Original.

Before we conclude our discussion of the attack force medical service, it may be well to relate the part played by the medical service of the embarked troops while they are still a part of the attack force. En route to the target, troop medical personnel will assist the ship's medical department to the extent of making sick call on their own troops and inspecting troop berthing and food preparation facilities. During the initial stages of the landing, those medical personnel who are not landed early (hospital elements) will assist the ship's medical department in the handling of casualties until called ashore. Occasionally, when the operation is such that hospital elements of the landing force will not in all probability be utilized ashore, they may be used to staff a special LST, to act as an auxiliary hospital ship in close support of the landing. In several operations in the South Pacific, these vessels actually beached, and casualties were brought directly aboard by ambulance.

The Landing Force.—Although the medical service afloat must bear the greatest burden of definitive casualty care in the early stages of an amphibious operation, the medical service of the landing force probably faces more problems in the exercise of its mission. The mere fact that it starts from zero on a hostile beach and builds up its service under a variety of conditions which cannot be too accurately predicted, requires that the personnel engaged be highly trained in their basic employment, in order that they may take advantage of whatever situation may confront them. Not the least of these requirements is the ability of the individual to exist and accommodate himself to the hardships, to conserve his energies for the task of casualty care.

Organization of the Marine Corps for Landing Force Operations.—The term "landing force" does not indicate in any way the numerical strength of the assault organization. We may have a landing force composed of two or more corps, or it may be as small as a battalion. It may be composed of both Army and Marine troops, which is designated a "joint landing force," or it may include troops of our allies, in which case it is a "combined landing force."



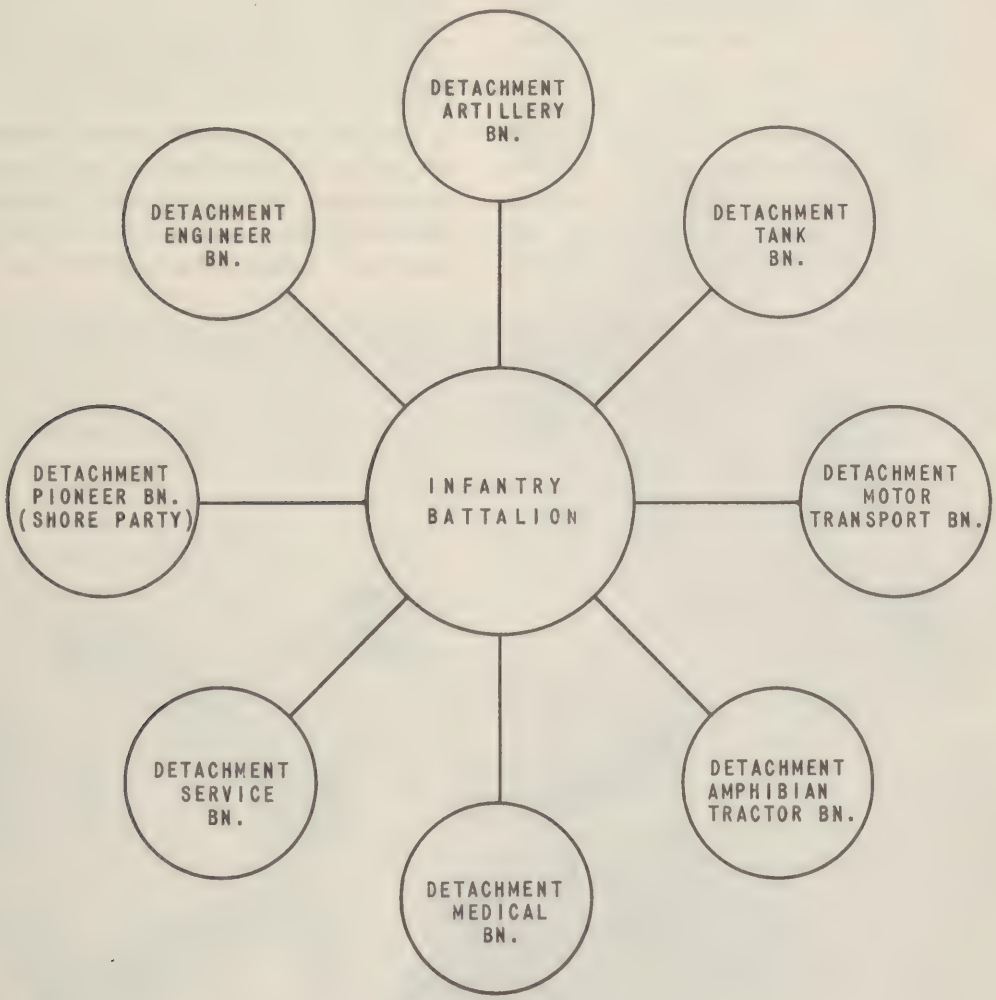
Note: All Infantry Regiments are divided as the one shown above.

Figure 13.—Composition of a marine division.

At this point, we will discuss only the organization of the Marine Corps as it is set up for landing force operations. The basic structure of the organization is triangular in nature. Thus we have a corps, (which is an organizational unit and is not to be confused with the designation of "marines" as the Marine Corps), composed of three divisions; a division which is composed of three regiments; and a regiment composed of three battalions. This basic structure refers to the infantry component, which, after all, is still the "Queen of Battles" in an amphibious operation.

The artillery is a separate regiment of the division not included in the "triangular structure," from which support is drawn as needed for a particular sector. There are also a number of separate battalions of specialized function. These separate battalions are the medical battalion, engineer battalion, tank battalion, amphibious tractor battalion, motor transport battalion, and service battalion, whose functions are obvious from their titles, and the pioneer battalion, which serves as the nucleus of the shore party, with the function of facilitating cargo unloading at the beach line.

The corps is chiefly a command echelon to coordinate the activities of the subordinate divisions. There are certain corps troop elements,



NOTE: These detachments vary from platoon to company in size (in case of Artillery, one or more Batteries) depending on the requirements for the particular mission of the BLT.

Figure 14.—Composition of a battalion landing team (BLT).

however, such as artillery, supply, and service units, and hospital elements that are directly under corps command and utilized to support the divisions where most needed.

The components of a marine division and their functions are fairly stabilized and will be discussed in some detail.

The reader is referred to the chart (Figure 13, page 46) showing the over-all structure of the division. It will be noted that the triangular structure continues down through infantry regiments, battalions, companies, and platoons.

The basic combat element in this structure is the battalion landing team (figure 14). It can be readily understood that in the initial phases of a landing operation, it is necessary that the infantry battalion commander have immediate control over all of his supporting elements. For this reason, detachments of company size or less are initially detached from their parent battalion, i.e., artillery, medical, tank, etc., and attached directly to the infantry battalion. This composite force is known as the battalion landing team (BLT). These detachments remain under infantry battalion control during the entire battalion phase of the landing. When the situation becomes more stabilized, the regimental headquarters assumes control of the three BLT's, and their attached supporting elements are combined. Such an organization is called a regimental combat team (RCT). Eventually, the division headquarters is established ashore and supporting units are released by the RCT's to their parent battalion and directed by the division commander. The division commander also exercises control over the three RCT's at this time. It must be borne in mind that the marine organization is so flexible that all or any part of the above organizations can be split off and reorganized almost overnight to act as an independent force. Thus, we may have various provisional brigades, reinforced regiments, and the like.

The mechanics of the initial landing may serve to give the reader a better appreciation of the intricacies and timing involved. Those who have not landed against a well-defended beach may have a tendency to regard the operation up to this point

Figure 15.—Company aid man. Removing casualty in a hurry under direct fire.

as merely a trucking operation, using vessels and landing craft instead of wheeled transport. Nothing could be farther from the truth. To gather together all the elements that make up an amphibious task force, have them carry out their assigned missions, and arrive and land at a particular target area with their greatest impact at almost the given minute that was planned months beforehand—this is an almost unbelievable miracle of coordination. Let us take the sequence of events for the actual landing.

Pre-invasion pounding of targets has already taken place by naval gunfire and air bombing. Minesweepers have cleared the way for the vessels of the attack force. Underwater demolition teams have swum in at night to destroy mines, wire, and other obstacles that might hamper the landing. On D-Day, the expeditionary troops, making the initial assault, are embarked in landing craft and formed into waves. This boat assignment is no haphazard affair, as the troops must hit the beach in a definite tactical formation in order to be able to quickly organize on the beach and push the attack. Naval gunfire, which has heretofore concentrated on known targets, such as gun emplacements, ammunition dumps, roads, and bridges, now shifts directly to the landing beaches; moving in close, they deliver point-blank fire. As the landing craft form into their waves, the smaller rocket ships move in, and for their few minutes plaster the immediate landing beaches with rockets to numb the defenders and explode land mines. As the landing craft cross the line of departure, as marked by control ships, and head for the beach, strafing planes come in with machine guns and rockets, paralleling the beach, to keep the defenders from manning gun positions. This neatly timed fire from naval guns, rocket ships and planes, keeps up until the leading landing craft are within 200 yards of the beach. Then it shifts to targets further inland. The leading landing craft, which are usually armored LVT's, do not stop at the beach but plow inland up to 300-400 yards, bypassing small enemy pockets. The subsequent waves, on landing, advance immediately and clear out this resistance. There follows a short period of reorganization and then the attack is pushed until the prearranged objective line for the day is reached.

Meanwhile, on the landing beaches, supplies of vital ammunition, food, and water, and reserve troop units are landing to build up the forces ashore for continued operations.

ORGANIZATION OF THE MEDICAL SERVICE OF THE LANDING FORCE

In discussing the organization, capabilities, and functioning of the medical service of the landing force, we shall first discuss the individual medical units from this standpoint and then describe the chain of evacuation, through which a casualty passes from the front lines to the landing craft in the various phases of the operation ashore. To facilitate understanding, we shall divide the

Figure 16.—Company aid man. First aid completed. Starting the casualty on the chain of evacuation.

various medical organizations into two groups. First, the organic medical sections of the various military units, such as battalions, regiments, and separate battalions. Secondly, we will describe the strictly medical organizations which are assigned to give hospital support.

ORGANIC MEDICAL SECTIONS

1. *Infantry Battalion Medical Section.*—This section consists of 2 medical officers and 40 hospital corpsmen, reinforced by litter bearers. They are an integral part of the infantry battalion with which they serve, train, and fight. The section is divided into the aid station personnel and the company aid men. The company aid men are assigned two to a rifle platoon, and the remaining corpsmen and medical officers comprise the aid station group.

a. *Company Aid Men.*—These personnel land in the assault with their respective platoons and stay with them throughout the fighting, maintaining a position within 100 to 150 yards to the rear of the front line. Their medical equipment consists of the unit I, kit, medical, first aid. Their first duty is to remove the casualties from the direct line of fire to a position of relative safety. They administer first aid as indicated. It may include checking of hemorrhage, application of a battle dressing, relief of pain by administration of morphine, and the application of splints to fractures. An emergency medical tag is filled out and secured firmly to the casualty's clothing. Company aid men then either mark the location of the casualty so that the litter bearers may find him or, if time permits, direct the activities of the litter bearers in removing the casualty on the route to the aid station.

b. *Aid Station Personnel.*—These personnel land in the fourth and fifth waves of the assault, divided into two echelons, each headed by a medical officer. They establish an aid station on landing and receive casualties brought in by the litter bearers. Their medical care consists of such measures as are indicated to put the patient in condition to be further evacuated. In addition to further first aid, they administer plasma and whole blood for the prevention and treatment of shock. Their equipment consists of unit I's plus combat medical packs, containing morphine, plasma and whole blood, serum albumin, battle dressings, and penicillin. This equipment, plus litters and splints, is hand-carried by individual corpsmen during the landing. A jeep ambulance, containing more splints, plasma, blankets, and a sick call chest is landed at the earliest possible moment.

c. *Litter Bearers.*—Litter bearers are drawn from nonmedical personnel of the battalion and are assigned to their work directly under the battalion medical officer. They are dispatched forward to the rifle company zone of action and evacuate casualties to the aid station.

2. *Infantry Regiment Medical Section.*—This section is composed of two medical officers and 12 hospital corpsmen. They land at approximately the same time as the regimental commander and establish an aid station in the vicinity of the regimental command post. They may or may not become a link in the chain of evacuation, depending on the road network from the battalions. Their function is to take care of such casualties as occur in the regimental headquarters area, to coordinate evacuation from the three battalions of the regiment, and to reinforce them with medical supplies and personnel as needed.

3. *Artillery Medical Section.*—The artillery regiment medical section is composed of one medical officer and eight hospital corpsmen, and the artillery battalion medical section has a like number. They land with the regiment or battalion headquarters to which attached and set up aid stations for the care of casualties among artillery personnel. The hospital corpsmen are assigned on a basis of two per firing battery. The aid stations are not a link in the chain of evacuation. Casualties that occur among artillery personnel are evacuated by jeep ambulance to the nearest element of the chain. This section carries much the same equipment as the infantry medical sections, but in lesser amounts.

4. *Separate Battalion Medical Sections.*—These sections are part of the various separate battalions, i.e., tank, amphibian tractor, motor transport, and engineering battalions, and normally consist of one

Figure 17.—Litter bearers. On the way to the battalion aid station.

medical officer and 8 to 12 hospital corpsmen. They function in much the same manner and with the same equipment as the artillery medical sections.

5. *Shore Party Medical Section.*—The shore party is the organization built up around the pioneer battalion, to handle the transfer of cargo from the landing craft to the supply dumps. The size of the shore party is determined by the conditions to be encountered on the beach. Thus, if there is a sandy beach with little surf, where LCVP's can easily bring palletized supplies high and dry, there is not the need for as many personnel as would be required if the landing craft had to be unloaded by hand. Similarly, the medical department is built up to enable it to accomplish its function of receiving casualties from the forward aid stations, giving further first aid and loading them in the landing craft, in accordance with previous estimates. Under normal conditions this can usually be accomplished by one medical officer and eight hospital corpsmen on each BLT beach. As evacuation becomes more centralized in the later stages of the operation, these sections are consolidated to man a central shore evacuation station and personnel not needed for this function are sent forward as replacements where needed.

HOSPITAL ELEMENTS

1. *Division Medical Battalion.*—This battalion is one of the separate battalions referred to previously. It is commanded by a medical officer with the rank of commander and consists of six companies: one headquarters and service company, two hospital companies, and three collecting and clearing companies. The main functions of this battalion are to: (1) further evacuate casualties from the aid stations; (2) give medical care, including complete definitive treatment and hospitalization, to those whose condition precludes further evacuation; and (3) give logistic support to the organic medical section.

a. *Headquarters and Service Company.*—This company includes the following sections:

(1) Medical supply section, which not only is responsible for supplying the various medical companies, but also the organic medical sections. Their function will be further discussed under the medical supply system of the landing force.

(2) The record section, which handles all personnel and medical reports required by regulations.

Figure 18.—Battalion aid station. Supportive measures.

Figure 19.—Battalion aid station. Shock therapy.

(3) A sanitary and preventive medicine section, which conducts surveys to ascertain what preventive medicine measures are indicated, and supervises the entire sanitary and preventive medicine program of the division.

(4) A dental section, consisting of 21 dental officers and their assistants, who operate a dental clinic during the bivouac period.

(5) A maintenance section, for maintenance of motor transport and other mechanical equipment.

This company is not necessarily entirely committed in an amphibious operation. For instance, the dental section is usually not necessary during the period of active combat and is left with the rear echelon of the division. The various sections land on order of the medical battalion commander when the tactical situation demands or permits their utilization.

b. *Clearing and Collecting Companies.*—These companies each consist of 4 medical officers, 1 dental officer, 1 MSC officer, 79 hospital corpsmen and 23 enlisted marines. They are divided into a clearing platoon and a collecting platoon. The clearing platoon operates a 60-bed surgical installation in immediate support of the regimental combat team to which assigned. They are equipped with a complete surgery mounted on a trailer and are extremely mobile. They confine their definitive surgical care and hospitalization to those cases which are classed as non-evacuables. The collecting platoon is further divided into three collecting sections of 16 hospital corpsmen each, one such section being in direct support of each of the three BLT's of the regiment. These sections land directly in back of the battalion aid station and

their function is to evacuate casualties along the line of evacuation from the aid stations to the beach. When the situation becomes more stabilized and battalions are consolidated under regimental control, these sections likewise are consolidated and work under the control of the regimental surgeon. Finally, when the parent clearing and collecting company is established ashore, they revert to control of that company but continue to evacuate casualties from the aid stations.

c. *Hospital Companies.*—These companies each consist of seven medical officers, one dental officer, one MSC officer, 57 hospital corpsmen and 26 enlisted marines. They land on order of the medical battalion commander, when the tactical situation permits their utilization, and establish a fully equipped 200-bed hospital. They are usually set up in the rear of the division zone of action as the "division hospital," but as the fighting progresses they may leapfrog along the main line of evacuation. Their function is to provide surgical and medical care and hospitalization ashore for casualties which, in accordance with the evacuation policy, are not to be further evacuated to task force facilities.

2. *Corps Hospital Elements.*—When the landing force consists of two or more divisions, making up a corps, further hospital elements are transposed in the chain at a corps level. These are the corps medical battalion and the corps evacuation hospital.

Figure 20.—Collecting section. Using jeep ambulance between battalion aid station and the medical company.

Figure 21.—Surgery in a dugout.

Figure 22.—Receiving casualty at division hospital.

a. *The Corps Medical Battalion* is roughly the size of three hospital companies and is so organized that they may split into three units if necessary, to give close support to divisions. Usually, however, the road network permitting, they function as a single unit. Their function is much the same as the division hospital companies as regards the professional care and hospitalization they provide.

b. *The Corps Evacuation Hospital.*—This is a large, well-equipped, and well-staffed, but somewhat immobile medical unit that is committed to the landing after the situation is fairly well stabilized. It consists of 20 medical officers, 2 dental officers, 5 hospital corps officers, 145 hospital corpsmen, and 60 nonmedical enlisted Marines, and is capable of operating a 600-bed surgical installation. This organization may function in several ways, depending on the tactical situation. Initially, medical officers and enlisted assistants may be utilized as surgical teams to augment the medical service of the forces afloat, such as APA's and LST casualty control boats. Later, these personnel may be assigned to reinforce the division or corps medical battalion units; and finally, when the hospital is committed to the engagement ashore as an entity, these personnel revert to their parent hospital and provide a high degree of surgical and medical care in the various specialties.

THE CHAIN OF EVACUATION

The chain of evacuation is a continuous series of links consisting of medical installations through which the casualty passes on the way from the front

line to the eventual destination. As a general rule, the casualty is kept at or evacuated to the medical installation which is best equipped to handle the individual case. Thus, a man with a fairly minor wound may be evacuated only as far as the aid station and returned to duty after treatment. Again, the condition may be such that it is necessary to stop progress in the chain of evacuation at the clearing platoon level due to the demand for immediate surgical intervention. On the other hand, every effort is made to take casualties, whose injuries will preclude their further participation in the fight, as far along the chain as their condition allows.

The first man in the chain is the company aid man. The casualty then passes by walking, litter bearer, or jeep ambulance, to the battalion aid station. Thence, he is transported by personnel of the collecting section to the shore party medical section for evacuation in landing craft. The regimental medical installation may or may not be a link in the chain, depending on the road network to the rear of the battalions. When the clearing platoon of the clearing and collecting company is established, it becomes a link in the chain as do the hospital companies, when they are set up ashore. Corps hospital elements, when closely supporting a division, may act in the same manner as a hospital company. Usually they do not displace forward when once established.

Naturally, evacuation of the casualty does not wait until each link in the chain is established. Thus, initially, the company aid man, assisted by riflemen, may put casualties in any returning landing craft. The aid station, while still on the beach prior to arrival of the collecting elements and shore party evacuation section, will assume their function and load casualties directly into landing craft. The probable time of landing of the various elements is as follows: company aid man, immediately; battalion aid station, usually H-hour plus 20 minutes; collecting element, H-hour plus 90 minutes; shore party medical section, H-hour plus

Figure 23.—Division medical company installation in partially destroyed Japanese radio installation.

Figure 24.—Field X-ray.

8-24 hours; clearing platoon of clearing and collecting company, D-day plus 1; hospital company, D-day plus 2-3.

MEDICAL SUPPLY

Initial medical supplies and equipment of the organic medical sections and collecting platoons, sufficient for 3 to 5 days of operation, are carried in by hand or in the jeep ambulance. Immediate resupply is carried aboard a landing craft, called a "floating dump," which takes medical supplies into any section of the beach in immediate need. These supplies are secured by direct request to the logistic control vessel lying off each beach. Clearing platoons of clearing and collecting companies land their equipment and supplies, sufficient for 5 days' operation, combat-loaded on their vehicles. Hospital companies land as much of their equipment as possible, combat-loaded in their vehicles, and the remainder is landed and placed in medical dumps from which it is secured as needed to erect the installation.

Bulk supplies, sufficient for the number of days' operation of all elements of the Medical Department, as directed in the logistic plan, are landed with general unloading of the ships, placed in medical dumps, and distributed on informal request to all elements, under the direction of the headquarters and service company medical supply section. This medical supply section also receives resupply items from the medical supply section of the combat service group supporting the operation, and distributes them as previously described.

The initial allowance of medical equipment and supplies of any unit of the Medical Department of the landing force is outlined under Class 9 items in the *Medical Supply Catalog*. Lists of blocks of supplies, estimated sufficient for 10 days for 3,000 men, 30 days for 3,000 men, and 30 days resupply for 3,000 men, are available at all major commands.

These blocks may be requisitioned as one item, without listing the component supplies. Items of medical supply or equipment of a special nature for operations in tropical or cold climates, or needed for specific disease conditions to be encountered, must be ordered separately.

CASUALTY REPORTS

Each echelon of the Medical Department maintains a running log of all patients passing through their installation. This log shows the name, rate, serial number, organization, descriptive diagnosis, and disposition of each casualty. At 24-hour intervals, the entries in this log are transposed to a casualty report form and submitted to the organization casualty reporting officer. In addition, hospital elements make out a daily report for submission to the division surgeon or the corps surgeon, showing their bed status, and the number of casualties awaiting air or sea evacuation. All medical installations keep a copy of their daily casualty report form, from which information is gathered to make out strictly Medical Department reports, such as "F" cards and form "N's."

STANDING OPERATING PROCEDURE FOR THE MEDICAL DEPARTMENT

At the risk of repetition, the following document, which is the standing operating procedure for the Medical Department now in effect in the Marine Division, is quoted in full.

1990–75–10
210–stp

HEADQUARTERS,
SECOND MARINE DIVISION, FLEET MARINE FORCE,
CAMP LEJEUNE, NORTH CAROLINA

24 October 1947.

MEDICAL, STANDING OPERATING PROCEDURE

DIVISION GENERAL ORDER)
NUMBER.....150.....)

Figure 25.—Surgery in a division medical company.

Figure 26.—Shore evacuation station. Supportive therapy is continued when needed at all installations.

1. GENERAL

a. The Senior Navy Medical Officer of the Division is normally assigned as Division Medical Officer on the Special Staff of the Commanding General. He is responsible to the Commanding General for the health of the Command. He shall advise the Commanding General on the tactical employment of all medical units of the Division and recommend various measures in regard to sanitation and preventive medicine and general policy in the care of the sick and wounded.

b. The Medical Battalion Commander is the administrative head of the Medical Battalion and has additional duty as Assistant Division Medical Officer. He will act in the absence of the Division Medical Officer.

c. Medical Company Commanders are the administrative heads of their respective companies and will carry out the directives of the Medical Battalion Commander unless assigned to other organizations for operational control. In such circumstances they will be responsible directly to the commanding officer of the organization to which assigned for such operational control.

d. Unit Medical Officers have the same responsibilities and functions in their organization as the Division Medical Officer has in the Division, in addition to giving medical care to the sick and wounded.

e. During combat operations, until otherwise directed by the Commanding General, Dental Officers of Division and Regimental Staffs will be assigned duty as assistant to Medical Officer with the specific function of carrying out directives in regard to evacuation of the sick and wounded.

f. Medical, Dental, and Hospital Corps Officers and Hospital Corpsmen, when directed by the Commanding General, will bear arms to protect themselves and their patients.

2. OPERATION OF THE MEDICAL DEPARTMENT IN BIVOUAC OR GARRISON

a. The functions of the Medical Department will be carried out in accordance with the *Manual of the Medical*

Department and current directives of the Bureau of Medicine and Surgery.

b. As a general policy, the medical department will make every effort consistent with sound medical care to utilize available facilities for the treating of the sick and injured within the division.

c. All medical units will engage in field training with the organization to which assigned or attached to the maximum extent. Medical Department problems will be included in the curriculum of organizational maneuvers whenever practical. Basic training of Hospital Corpsmen will be carried out.

d. All members of the command will be instructed in first aid, personal hygiene, and sanitation.

e. Prior to operations in the field, the following special procedures will be carried out:

(1) Elimination of the physically unfit.

(2) Completion of all routine inoculations and special inoculations as may be directed.

(3) Check health records with the organization rosters. Duplicates will be made for those individuals whose health record is missing.

3. EMPLOYMENT OF THE MEDICAL DEPARTMENT IN COMBAT OPERATIONS

A. ORGANIZATION.

1. Battalions, Regiments, and Separate Battalions, medical stations according to Tables of Organization.

2. Medical Battalion:

a. One Collecting and Clearing Company will be assigned in direct support of each Combat Team.

b. Collecting Platoon of Collecting and Clearing Company will be divided into three (3) sections, one section supporting each BLT.

c. Headquarters and Service Company, Medical Battalion plus Hospital Companies comprise Division Hospital.

3. Shore Party Medical Section:

a. Medical Sections of Shore Party Teams will consist of four (4) Hospital Corpsmen.

b. Medical Sections of Shore Party Groups will consist of one (1) Medical Officer and six (6) Hospital Corpsmen.

c. Medical Sections with Division Shore Party Headquarters will consist of one (1) Medical Officer and six (6) Hospital Corpsmen.

Figure 27.—Shore evacuation station. Casualties being transported to landing craft.

Figure 28.—Loading the landing craft.

d. Medical Officers and Hospital Corpsmen to fill this complement will be assigned from over-strength allowance of the Division.

4. When circumstances indicate that additional litter bearers are needed due to expected heavy casualties or terrain features, litter bearers will be produced from available service troops and assigned to Battalion Medical Sections.

B. TACTICAL EMPLOYMENT.

1. Aboard Ship:

a. Troops' Medical Officers will hold sick call among troops embarked.

b. Sick Bay space, supplies and equipment will be furnished by the ship in which embarked.

c. Inspection of food preparation and living spaces will be held by Troop Medical Officers who will report deficiencies to the Commanding Officer of Troops.

d. Medical Companies will initially assist in handling of casualties until ordered ashore.

2. Ship to Shore:

a. Medical Personnel will be boated and landed as follows:

1. Company Aid Men: with respective platoons.

2. Battalion Aid Station: divided in two sections boated in last two waves of first trip of boats and landed on schedule.

3. Regimental Aid Station: approximately same wave as RCT Commander.

4. Collecting Section: first wave of second trip of boats. Will report to control boat;. to land on order of unit to which attached.

5. Shore Party Medical Personnel: approximately same wave as Shore Party Team, Group or Headquarters Commander.

6. Clearing Platoon Section of Assigned Medical Companies: on order when tactical situation permits.

7. Medical Battalion (less detachments): on order when tactical situation permits.

8. Medical Personnel with Division Troops: approximately same time as Battalion Headquarters.

Figure 29.—Amphibian tractors utilized for evacuation.

Figure 30.—Reef conditions sometimes necessitate use of rubber boats from the beach to landingcraft.

3. Ashore:

a. Company Aid men give first aid in platoon zone of action.

b. Battalion Aid Station reinforced by litter bearers evacuate wounded from front to aid station and give treatment necessary to put patient in condition for further evacuation.

c. Regimental Aid Section will establish aid station in area of Regimental CP; treat casualties (in zone of action) and coordinate evacuation from Battalions.

d. Collecting Sections will initially assume function of Shore Evacuation Station until relieved by Shore Party Medical Section. They will treat all casualties in zone of action. As aid station deploys forward, collecting sections will accomplish evacuation from aid stations to beach. When tactical situation permits, collecting section less jeep ambulances and drivers will revert to parent medical company.

e. Clearing Platoons will establish 60 bed hospitals when directed. They will revert to Division control as soon as tactical situation permits.

f. Medical Battalion (less detachments) will establish Division hospital on order.

g. Shore Party Medical Section will assume operation of the shore evacuation station on landing. As evacuation becomes more centralized and evacuation stations are consolidated, medical personnel of these sections will be utilized as replacements for forward medical installations on Division order.

h. Medical Sections of separate battalions and other detachments will establish aid stations in area of unit command post and treat and evacuate casualties occurring in their immediate area.

C. EVACUATION.

1. Policy:

Initially, immediate evacuation to the beach by litter or any vehicle available, and to casualty control vessel off shore by any amphibious tractor or landing craft available. When medical companies become established ashore, evacuation will be in accordance with policy as set forth in medical plan.

Figure 31.—LST utilized as casualty reception and distribution vessel.

Figure 32.—Single litter hoist from landing craft to APA.

2. Chain of Evacuation:

Evacuation is through a continuous series of links starting initially with the company aid man and progressing as other units become established ashore. Developing in order of their landing, these links will normally be the company aid man, the battalion aid station, the collecting section and the shore party medical section. The Regimental Medical Section may or may not be a link in the chain, depending on the tactical situation and the road network to the rear of the battalions. A further link is interposed in the chain between regiments and the beach on establishment of the Clearing Platoons.

3. When division hospital is established ashore, all casualties will channel through this activity. Definitive care of all casualties will be carried out to the limit of capacity with due regard for evacuation policy in effect and the necessity of maintaining a degree of mobility.

4. Casualties among our Nationals will be evacuated along normal channels and disposed of in accordance with medical plan, either to ships or Civilian Affairs Camps.

5. P.O.W.'s will be given treatment to the limit of medical facilities, not however interfering with the treatment of our troops, and will be disposed of in accordance with the medical plan, either to ships, concentration camps or stockades.

D. EQUIPMENT AND SUPPLIES.

1. All medical personnel will be equipped with medical pouches according to Table of Equipment.

2. Initial requirements of vital items will be available for debarkation with medical personnel of battalions, regiments, separate battalions, collecting sections, and shore party medical sections.

3. Immediate resupply will be combat loaded in organizational ambulances. These ambulances will be given high priority in unloading of organic vehicles.

4. Emergency resupply of vital items to any section of regimental beach head will be carried in floating dump and may be secured on call to logistic control vessel.

5. Equipment and supplies of clearing platoons and divisional hospitals sufficient for initial surgical installations and 5 days' operation will be combat loaded on their organic transportation.

6. Remainder of medical supplies will be handled in accordance with division logistic plan.

7. Resupply of units in combat will initially be direct from the next echelon to the rear on informal request.

8. Each Collecting and Clearing Company supporting a

regiment will normally carry 20% of bulk medical supplies of the division.

9. Division hospital will normally carry remaining 40%. They will establish division medical supply section and resupply forward units on informal request.

10. Resupply, other than that carried in accordance with division logistic plan will be handled by the medical supply section of the Combat Service Unit attached. Distribution will be through division medical supply section of division hospital.

E. GENERAL PRINCIPLES OF CASUALTY HANDLING.

1. Emergency medical tag will be completed and attached to clothing of all casualties by the first member of the Medical Department who contacts the casualty.

2. The cardinal principle in treatment of a casualty by forward units is to put the patient in condition so that he may be further evacuated. Except in unusual circumstances, no casualties in shock will be evacuated if it is adjudged that transportation at that time will further endanger the casualties' chances of survival.

3. Clearing platoons supporting regiments will confine definitive treatment to those cases which are classed as non-evacuables and to any other casualties when further evacuation is impossible due to enemy interdiction, condition of road network, or other circumstances.

4. Division hospital will do all definitive work to the limit of its capacity with the following general exceptions:

a. When condition of casualty warrants and supporting hospitalization either ashore or afloat is available, casualties will be further evacuated without delay.

b. When services of specialists are indicated and are not available in the division hospital but are available to the rear, evacuation will be accomplished as soon as patient's condition permits.

c. When tactical plan indicates that large scale casualties are to be expected. In this case the division hospital will keep as many beds available as possible for new admissions, by evacuation of casualties to the rear.

5. As a general rule, all casualties who are expected to be fit for duty within limits of evacuation policy will be kept at echelon of the medical department where they may be best handled.

Figure 33.—Unloading landing craft at the half-rail.

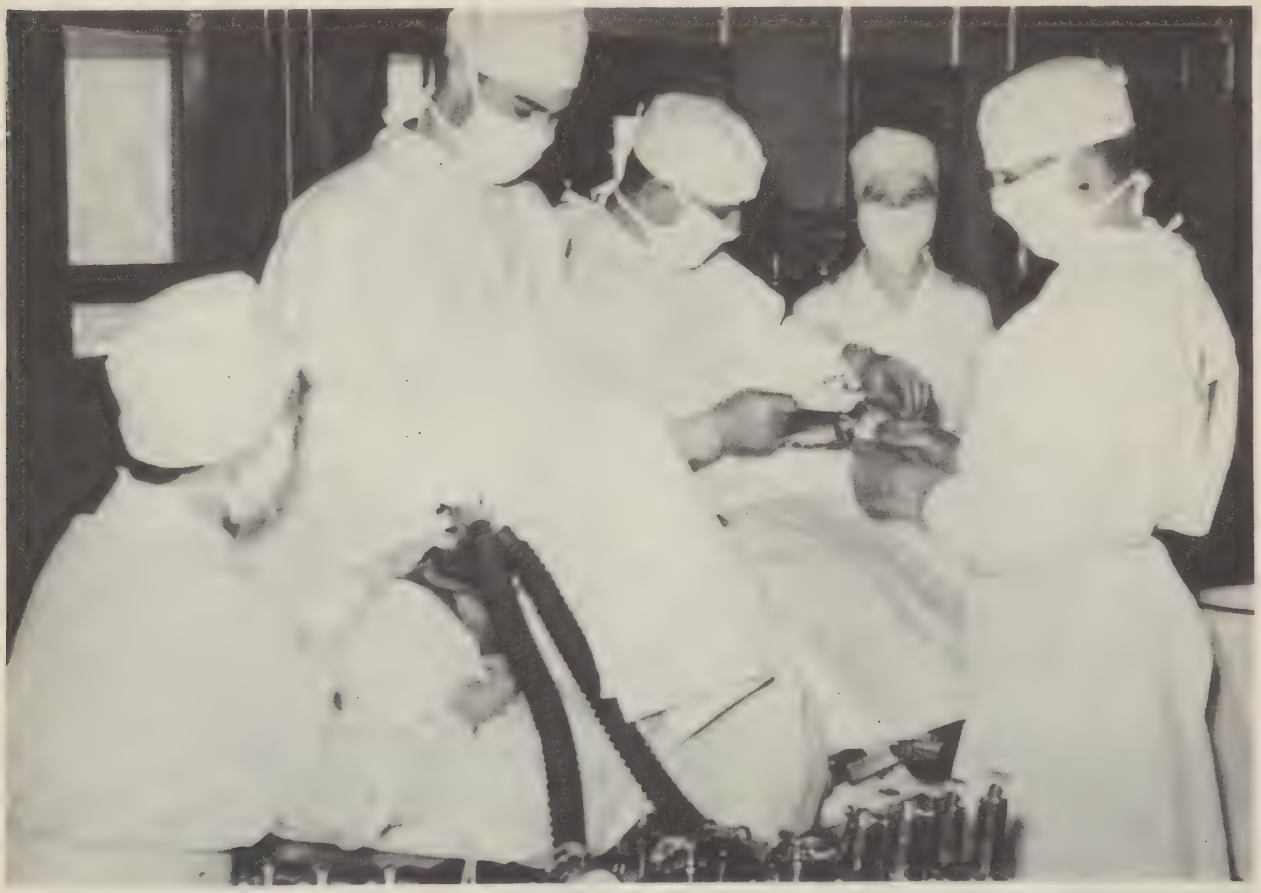


Figure 34.—Surgery aboard hospital ship.

F. CASUALTY REPORTS AND REPORTING.

1. All units of the Medical Department will maintain a running log of patients going through their installations containing information necessary to complete daily casualty forms as required by Division Administrative SOP (Div GO 112).

2. Reports to casualty reporting officers will be made by those concerned in accordance with Division Administrative SOP (Div GO 112).

3. All other Medical Department reports will be made in accordance with current directives, consolidated for the Division by the medical record officer of the Medical Battalion and approved by the Division Medical Officer prior to submission.

G. SANITATION: (See Sanitation SOP—Division GO #92).

BY COMMAND OF MAJOR GENERAL DOE:
JOHN JONES,
Colonel, U. S. Marine Corps,
Chief of Staff
ACTING

DISTRIBUTION:
"B" & "C"
OFFICIAL:
/s/ JOHN DOE
Captain, USMC,
Adjutant.

SANITATION AND PREVENTIVE MEDICINE

The control of disease among troops of the landing force has never received the attention that it merited. Our record of disease control in the past war was not altogether a happy one, although at least the impetus of war probably brought along more quickly certain methods of control that will play a part in the future. From a strictly military standpoint, the control of disease is more important than the care of battle casualties, there being several times more disease casualties than battle casualties on most operations of any length. One of the medical officer's greatest problems is to get that idea across to his commanding officer forcefully enough to get something done about it. Recently, some new methods of control have been introduced which may give us a large measure of protection with the use of a minimum of personnel. Two of these methods, airplane spray (which is not exactly new, having been used quite extensively on the later operations), and aerosol fogging of DDT by means of a combustion generator, give promise of

providing early control of fly- and mosquito-borne diseases. The aerosol fog generator, under favorable wind conditions up to 10 knots an hour, can lay an aerosol curtain, containing up to 15 percent DDT, with successful mosquito kills up to a mile in width. Used early in the assault (before dusk of the first night) it may be the answer to protection for the assault troops by killing off the infected adult mosquitoes in the beachhead area.

Several general principles of sanitation and preventive medicine should be mentioned before we go into the organization and function of those primarily charged with the disease control program. First, medical personnel do not do the actual work. That is, they do not dig the heads, spray the DDT, dispose of the refuse, etc. The actual labor details are drawn from personnel so ordered by the commanding officer. In some cases, late in the operation, prisoners of war may be employed if available. Second, while medical personnel do not do the actual work, they must get out into the field and personally see that the work is done properly and not merely content themselves with writing orders about it. In other words, their function is to survey, advise, inspect, supervise, and direct measures for both routine sanitation and preventive medicine. Third, since the preventive measures indicated depend a great deal on the conditions at the target area, every scrap of intelligence that is available regarding these conditions must be made known to the medical officers charged with the control of disease during the planning phase.

The following personnel, functioning as listed, comprise the organization primarily concerned with disease control in a marine division.

1. The commanding general and commanding officer of all subordinate units: Regardless of rank, they are personally responsible for enforcement of sanitary measures within their areas and the boundaries of areas occupied by them. They will take such steps as are deemed practical and feasible to correct sanitary defects as recommended by the medical officer.

2. The division surgeon: Advises the commanding general as to what measures are necessary, writes orders for implementing the program, and does such inspections as are necessary to insure that the program is being carried out.

3. Medical officers of all elements:

a. Will make sanitary inspections at least once weekly in bivouac, and daily in the field, of all sanitary installations in their area.

b. Will supervise the activities of the sanitary control men of their activity.

c. Will make routine reports and recommenda-

Figure 35.—The floating hospital of the navy.

tions to their commanding officer regarding disease control measures and special reports as indicated regarding any unusual health hazards encountered.

d. Will request additional personnel as needed from their commanding officer to adequately carry out measures indicated for disease prevention.

e. Will assure themselves that all personnel are inoculated with both routine and such special inoculations as are indicated.

f. Will indoctrinate all troops of their unit in the method, means, and nature of individual precautions to be taken in the prevention of disease.

4. The malaria and epidemic control section of the headquarters and service company of the medical battalion:

a. Will plan and coordinate large-scale preventive measures.

b. Will direct the implementation of such large-scale measures, using service troops or POW's, as available, for actual labor details.

c. Will make such inspections as are necesary to see that all routine measures are being adequately carried out throughout the division and report deficiencies to the division surgeon.

d. Will make such further inspections as are necessary, and make recommendations to the division surgeon regarding the presence of any special health hazards.

e. Will make field surveys and laboratory examinations to identify vectors and disease organisms.

f. Will conduct training program for indoctrination of sanitary control men of all division units.

g. Will supervise the distribution of all epidemic control supplies for all division units.

h. Will assist in the preparation of routine sanitary reports and make such special reports of disease incidence as required by regulations.

i. If practicable, they will make a survey of the native population for determination of parasitic incidence.

5. Sanitary control squads: Each military unit of battalion size has a battalion sanitary squad of three marines, whose primary duties are the carrying out of routine sanitary measures. These personnel are given a formal course of instruction by the staff of the malaria and epidemic control section and work directly under the supervision of the unit medical officer. Specifically, they carry out the following functions:

a. Secure and maintain the equipment and supplies necessary for taking routine sanitary measures. These supplies and equipment are drawn from the unit quartermaster. They consist of such things as DDT of various types, kerosene, knapsack sprayers, flytraps, rattraps, etc.

b. Supervise working parties in the actual construction of sanitary installations, such as heads, urinals, galleys, and mess halls.

c. Spray DDT and oil where indicated in their area for larval control and fly control. Heads, garbage dumps, slit trenches and other fly-breeding media are sprayed at regular intervals.

d. Erect flytraps and keep them in maintenance.

e. Distribute items for individual protection such as insect repellent, and louse powder.

f. Supervise the erection of Lister bags and their chlorination.

6. As before stated, working parties for large-scale measures are drawn as needed from service elements of the division.

One of the most important factors in the control of disease is proper indoctrination of the individual. There has been a decided tendency to be lax in this regard on both the part of the individual marine and the medical officers, since the advent of DDT. It must be remembered that every effort we can bend in the direction of disease control is necessary if the program is to be successful, and there is still no foolproof substitute for individual precautions and conscientious observance of routine sanitation and preventive measures.

It will be realized that preventive medicine measures will vary with the target, and that instructions regarding sanitation and preventive measures and the organization to carry out these measures will likewise vary. After consideration of all intelligence available regarding the magnitude of the preventive medicine problem, the unit medical officer writes a sanitary order, which is an annex to the

over-all operations plan for the engagement. This order outlines just what routine measures will assume special importance and what special precautions and protective measures will be taken. A copy of such an order for a marine division for a specific mission is quoted below in full. A 5 percent DDT solution in kerosene has since been substituted for sodium arsenite where its use is indicated.

ANNEX "A" TO ACCOMPANY ADMINISTRATIVE ORDER #35
SANITATION

2d Mar Div, Reinf.
In the field.
1000, 1 May 44.

1. RESPONSIBILITY

a. It is a command function to properly instruct all members of the command in sanitary measures and to insure that such measures are practiced.

b. It is the duty of medical personnel to inspect the areas for which their commanders are responsible and advise the commander on the status of sanitation.

2. ORGANIZATION

a. The Malaria and Epidemic Control Unit, as organized will be supplemented by personnel from the 18th Naval Construction Battalion as needed for general epidemiological control and sanitary inspection.

b. A sanitary squad of three enlisted men and one medical officer for each battalion will carry out sanitary procedures in battalions.

3. PROCEDURES AND INSTRUCTIONS

It is imperative that all organization commanders be cognizant of their responsibilities in maintaining proper sanitation. While there is no known malaria in the theatre, other insect-borne diseases, such as dengue, dysentery, and scrub typhus constitute a menace to the success of the operation. The following sanitary instructions will be carried out.

a. *Food:* Only "C", "D", 10-in-1, and "K" type rations will be eaten after landing until further order. Mess kits will not be used for consumption of these rations. No captured food will be used without inspection by a medical officer.

b. *Water:* Initially, only water from containers brought from transports will be used. No water from local sources will be used until authorized by a medical officer and this will be chlorinated prior to consumption. Purification units will be established as soon as taken ashore. (See Annex "F" to Adm O #35).

c. *Disposal of Wastes:*

(1) *Food Wastes.*—During combat phase, all cans, wrappers, containers, and unfinished rations will be crushed and buried by the individual user. As soon as the situation is stabilized, central pits for the disposal of garbage and other waste material will be established and individual disposal will be prohibited. Garbage and rubbish pits will be sprayed daily with a solution of Sodium Arsenite and at the end of the day the residue will be layered over with earth. When the pit is filled to within 18 inches of the ground level, it will be filled in and mounded to a height of two feet and plainly marked as a closed garbage pit. Soakage pits for liquid galley wastes will be constructed before the galley goes into operation. Soakage pits will be sprayed daily with Sodium Arsenite.

(2) *Human Wastes.*—Initially, all personnel will defecate in a hole at least one (1) foot deep and cover the deposit with earth. Straddle trenches will be established as soon as feasible. Individuals using them will cover the deposit with earth. Box type latrines will be utilized as soon as possible and sprayed with a solution of Sodium Arsenite. Permanent heads will not be established within 50 yards of a bivouac area or 100 yards from a galley.

d. *Personal Hygiene.*—All personnel shall comply with the fundamentals of personal cleanliness and frequent inspections will be made by commanding officers to insure that personnel are utilizing the available facilities to the utmost.

e. *Insects.*—Insects in the area carry two diseases of importance; dengue, carried by Aedes mosquitoes; and scrub typhus, carried by mites.

(1) The following mosquito control measures will be carried out by all hands: Clothes will be worn at all times. Sleeves will be rolled down, legs kept covered. Since the Aedes mosquito bites around the ankles, leggings will be worn or pants will be tucked into socks. Repellent will be applied to all exposed parts of the body, and on parts of the body where clothes are tight fitting. Repellent lasts about four hours. Keep in mind that Aedes often bites unnoticed. Bed nets will be used wherever practical. All actual and potential Aedes breeding places—cans, pot holes, ruts, tires, cocoanut halves, beached boats, etc.—will be buried or oiled weekly.

(2) The following measures will be followed in prevention of mite bites: Clothing will be worn at all times. Insect repellent will be daubed lightly on inner surface of collars and cuffs of shirts, and cuffs of trousers before leaving the ship. This will remain effective for 5 to 6 days, after which it should be repeated. Keep legs well covered on all patrols into grassy lands, or native villages. On returning to base, bathe thoroughly and wash clothes, preferably in hot, soapy water. Report all bites from unknown sources, especially around the belt line, to the medical officer at the sick bay.

f. *Native Villages and Habitations.*—Native villages and habitations are off limits to members of this command except when entered in the performance of duty. All members of this command are prohibited from traffic or relations of any sort with members of native communities except in an official capacity. Natives are frequently the source of infection with yaws, dengue fever, syphilis, scrub

typhus fever, and dysentery. Necessary sanitary measures will be instituted among the native population in order to protect the health of service personnel. Medical care of the natives will be provided when necessary to prevent the spread of communicable diseases.

DOE:

OFFICIAL:
SMITH

AIR EVACUATION

Little has been said previously of the part air evacuation plays in the chain of evacuation as to command relationships; assigned responsibilities and services provided are almost a separate entity.

Air evacuation may or may not play an important role in an amphibious operation, depending on the length of the engagement and the facilities for operation of aircraft that can be captured or developed on the target. Incidentally, air evacuation became an increasingly valuable adjunct in the later stages of the last war, at least half of the casualties on the Okinawa operation being evacuated by this means.

Both land planes and flying boats are utilized as early as facilities for their operation can be made available. Under some circumstances, where the evacuation chain between the front and the hospital elements ashore becomes unduly lengthened or impassable due to the condition of the road network, cub planes, capable of carrying one litter case, are employed. Cases for air evacuation must be carefully screened, as chest cases and some brain injuries do not tolerate the changes in air pressure occasioned by high-altitude flying. On the whole, however, most cases that can be transported by any other means can be handled by air.

During the planning phase, estimates of the assistance that can be given by air evacuation are made by the joint expeditionary force surgeon, and a request for the required services is made to the fleet air commander. It is then the responsibility of the air command surgeon to insure that planes employed for this service are adequately equipped and staffed with medical personnel, and that a medical unit is provided to screen the casualties at the target prior to their being placed in air evacuation planes.

Once air evacuation becomes feasible at the target, the expeditionary force commander will notify and request the theater air commander, or his representative, who is usually located at the advanced base from which the planes operate, to start air evacuation service. The coordination of the evacuation from various hospital elements to the

Figure 36.—Cub plane used to supplement field ambulances in evacuation from the forward area.

Figure 37.—Nursing care to casualties evacuated by C-54 air transport.

air fields then becomes a responsibility of the landing force surgeon. He maintains close liaison with the flight surgeon at the air fields to learn the time of arrival and capacity of evacuation planes and informs the various hospital elements of the number of casualties to be transported to the air field at various times.

In the foregoing chapters, we have discussed the organization, function and method of employment of the medical service. The reader might well ask just how he, as a staff medical officer, gets things done, what his duties are, and his authority. To begin with, a medical officer does not command, except in those situations where he is the commanding officer of a medical battalion or a corps evacuation hospital. His position, like that of other staff officers, is to advise the commanding officer of the military organization with which he serves. The comanding officer can delegate authority to certain of his staff officers to act for him, and certainly this occurs many times in dealing with strictly medical matters. As the saying goes, the staff officer may "wear the General's stars" in carrying out delegated missions in his particular field.

For instance, the division surgeon may see that it is necessary to move one of the medical units forward to a new location. After conferring with the operations officer to insure that this move is not contraindicated, he will request the commanding general to issue an order to the medical unit. On the other hand, if he "wears the General's stars" the division surgeon, after insuring that the move is not contraindicated from a military viewpoint, may request the commanding officer, who has cognizance of the particular medical unit in question, to carry out the movement. Such authority is not to be taken by the medical staff officer as a matter of course. He must, by frank discussion, come to an

understanding with the commanding officer as to just what degree of authority he will have in directing employment of the medical service. The following outline of the duties of a division surgeon will best serve to show his function in the division. Corps, regimental, and battalion surgeons bear the same relationship and have the same duties in their organization.

a. Advise the division commander on all matters pertaining to the medical service of the command.

b. Keep the division commander informed of the general health of the command and recommend measures necessary to maintain the health of the command at the highest peak.

c. Prepare all medical plans, directives and orders for promulgation by the division commander.

d. By frequent inspection, as necessary, supervise the entire medical service of the division in the following strictly medical matters:

(1) Efficiency of medical care of all echelons.

(2) Efficiency of sanitary and preventive medicine measures.

(3) Training of all medical personnel in their strictly medical duties.

(4) Training of nonmedical personnel in individual preventive medicine measures.

(5) Maintenance of proper records and required reports.

(6) Maintenance of medical supplies and equipment.

The foregoing resume of the role played by the Medical Department in amphibious operations is but an introduction to the detailed operation of the medical service. Further information on the subject can be gained from United States Fleet publications No. 6, 66, and 63, and from an excellent booklet prepared by Marine Corps Schools, Quantico, Virginia, entitled *"Medical Service in Amphibious Operations"* Phib-21. However, preparation of the medical officer for this employment cannot be gained solely from manuals or classroom instruction. To gain the necessary perspective, it is mandatory that personnel engage in field exercise and maneuvers with medical units in connection with military forces. Here the capabilities of the

Figure 38.—Air evacuation by flying boat.

various units are observed and the many problems whose solution must be learned, are simulated to a high degree. The practical aspects of living in the field, terrain appreciation from the standpoint of protective covering for medical installations and individual alike, evaluation of routes of evacuation and many other problems are best learned by participation in maneuvers with troops.

One role that the Medical Department plays in battle has never been given its proper evaluation. That is, the morale factor provided by efficient medical service in close support of the fighting troops. The certain knowledge on the part of the fighting man that he will be quickly evacuated and given the best possible medical care in the event he becomes a casualty, undoubtedly plays a great part in his willingness to advance against the enemy. Thus, by maintaining the morale of the assault forces, in addition to his life-saving care, does the medical officer serving with the amphibious forces, fulfill his mission.

HISTORY OF THE MEDICAL DEPARTMENT OF A MARINE DIVISION IN AN AMPHIBIOUS OPERATION IN THE PACIFIC*

The following account of an amphibious operation in the Pacific is taken from an article, written for official naval history. It is felt that this account will serve better than any academic instruction to bring home to the reader a true picture of the operation of the Medical Department of a landing force division.

"The Saipan operation lends itself well to a portrayal of our amphibious medical service, both afloat and ashore, at about the midphase of our offensive effort against the Japanese. There was both the furious resistance on the beachhead reminiscent of Tarawa and prolonged fighting over rugged terrain that gave the Medical Department an opportunity to establish itself fully ashore and assume its vital role.

"The initial assault on Saipan was made by the Second and Fourth Marine Divisions, with the Twenty-Seventh Army Division in support. The 5th Amphibious Corps under command of General H. M. Smith had the over-all command of the Landing Force. The following account concerns the activities of the Medical Department of the Second Marine Division.

"It is well to emphasize at the start that we had many advantages over those engaging in earlier campaigns. First, we had more of what it takes to successfully conduct an operation; more ships, planes, men, and supplies. Relative mastery of the sea and air was ours. Second, we did not have to contend with the host of tropical diseases, notably malaria, and the rigors of a tropical climate. Third, we had honest and forthright reports both written and verbal of preceding operations, pointing out mistakes and making recommendations for their correction. Fourth, fifty per cent or more of the medical officers and hospital corpsmen had been in combat and knew the demands to be made upon them. Fifth, and by no means the least important, we served with a force that had come, by bitter experience in battle, to appreciate the Medical Department, and who spared no effort to assist that department in training, planning and acquiring intelligence concerning the coming operation.

"To discuss an operation without comment on the training period that preceded it is to omit one of the most important phases of that operation. It is during this period that lessons learned in previous combat are evaluated and translated into operating doctrine, and replacements for those lost in previous combat are welded into a team that will act with automatic precision in the face of whatever hazards are encountered.

"The training period officially began on 15 January 1944, on the broad high plateau of the northern end of the 'Big Island,' Hawaii. Battalion, Regimental, and separate battalion medical sections, besides carrying on the routine sick bay activities, closely participated in all of their organization's field problems. The medical companies, for the first time, were bivouaced together under the administration of headquarters company of the medical battalion. These companies were rotated through three types of training. An Army hospital on the outskirts of the bivouac area provided hospitalization for our routine ineffectives and two medical companies and various specialists from other companies served on the staff. This allowed for basic training of technicians and kept professional interest alive. A field hospital in the bivouac area was staffed by two medical companies which

* As presented by Capt. E. R. Herring (MC) USN.

in addition to the foregoing, gave both medical officers and corpsmen a chance to thoroughly familiarize themselves with the equipment they were to work with in the field. The third type of training consisted of one month's participation in field problems and establishment of the medical company installation in a variety of locations and situations.

"Classes were held throughout the Division for basic training such as plasma administration, record and supply work, black-out precautions, evacuation of tanks, loading of DUKW's and amphtracs with simulated casualties, and many other details. Every medical officer and corpsman in the Division was given refresher training in the care and firing of small arms. Most of the company aid men on their own initiative mastered all of the various weapons carried by the Marines of their platoons, including the fifty caliber machine gun, bazooka, 37 mm gun, and light mortar.

"As a forerunner to actual planning, comment from all medical officers who participated in the Tarawa operation was secured and evaluated. It is to be emphasized that amphibious warfare is an ever developing science and that comments on any previous operations are to be considered, not in the light of mistakes which occurred, but rather as lessons learned. From these lessons learned, we evolved several elements of doctrine regarding supplies, equipment, and tactical employment, which appeared justified by past experiences.

"Experience had shown that the field units, as issued, were of little value for battalion and regimental use. On the way into the Tarawa beaches, many corpsmen had been hit and their equipment lost with them. Thus if a corpsman detailed to carry in the Unit 7 was lost, there was a shortage of battle dressings; if the men detailed to bring in the boxes of plasma became casualties, there was a shortage of plasma. The equipment and supplies as issued were too individualized. To offset this, assault medical packs made from the canvas carrying case and filled with vital items (battle dressings, plasma, morphine, and sulfa drugs) were prepared in identical loads for all units of the Division. These assault packs, plus litters and plywood splints, were the sole initial allowance of the battalion aid sections. The jeep ambulance allotted was further combat loaded with splints, litters, blankets, extra plasma, and a compact sick call chest.

"For immediate resupply, one amphibian tractor off each regimental beach was assigned to the Medical Department and carried a full load of litters, blankets, splints, and resupply units containing plasma, battle dressings, morphine, and sulfa drugs packed in fifty pound cases. These amphibian tractors were to lay along side the logistical control boat and be available to any section of the regimental beach on call.

"Medical Company equipment was combat loaded on their organic transportation in such a manner that when landed, they could proceed inland at once to their designated location and set up their initial surgical installation. The remainder of the supplies and equipment for thirty days was to come ashore when general unloading started.

"Because heavy casualties were expected on the beachhead, Collecting Sections were equipped and trained to function in the same capacity as Battalion Aid Stations. Also, it was believed that the Regimental Commanders would be too involved in the heavy fighting to assume responsibility for the assigned medical companies and the medical plan called for all companies to come under Division control once the transport areas were reached and to land on Division order only.

"One glaring error in the planning was the overlooking of the civilian casualty problem. Prior to this time, our operations had been on sparsely settled atolls or islands and the problem of handling large scale civilian casualties had not presented itself. This problem was to cause us much discomfiture as, early in the campaign, it fell to the Division medical service to give at least humanitarian care and we were to be taxed to the utmost to take care of our own wounded.

"Embarkation of medical personnel and equipment started the first week in April, 1944 and proceeded smoothly, due mostly to the direction of the medical officers who had attended the transport loading school.

"As dock space allowed only one Regimental Combat Team to load at a time, there was a continuous flow of equipment and supplies from our encampment at Camp Tarawa, sixty miles down to the docks at Hilo. A chart showing the location of

all medical supplies and equipment aboard the various transports was prepared and included in the adminstrative order. Medical personnel of the assault waves were loaded with their respective troops and medical companies were distributed among five transports to re-enforce them initially for casualty handling. The over strength allowance of medical officers was distributed among the LST's having no doctors aboard, to take care of troops enroute.

"A complete rehearsal was held on one of the islands of the Hawaiian group and then the transports put into Pearl Harbor for nine days shakedown and liberty, the last for more than twelve hundred of our men. Two serious accidents occurred during maneuvers and the nine day rehabilitation period, resulting in the loss of an unknown number of troops, including twelve hospital corpsmen. A hasty reorganization and re-equipping was accomplished and the task force got underway for the staging area, arriving at Eniwetok Atoll on the 7th of June. Up to five hundred troops were embarked on some of the LST's which was viewed with considerable apprehension by the Medical Department, especially if bad weather intervened, but no epidemics occurred and no demonstrable loss of physical stamina resulted.

"The morale of the troops was never higher; good food in a healthy climate and five months of hard training had molded them into a confident, poised unit. Two widely unrelated occurrences further cheered them, one, the long awaited landing in Normandy which caused an appreciative uproar on every ship in the convoy, and second, and closer to their immediate cause, a report was received that one of our aviators had parachuted from his disabled plane onto the very reef over which they were to land and had been rescued by a Destroyer after having spent two hours without drawing fire from the beach.

"D-Day for the Saipan operation was 15 June 1944, H-Hour, 0830. Long before that time our naval gunfire and bombing had been crashing into the beachhead and selected inland targets, until it was difficult to believe that anything could live in that area. This same impression had been rudely shattered at Tarawa, however, and every glass available was trained on the beachhead by those not in the assault wave as the leading amphibian tractors left the line of departure and wallowed in toward the reef. There followed breathless moments as they came closer and closer and then geysers of water could be seen in and around the first vehicles and all illusions of an easy landing were gone.

"The first casualties arrived at the transports at 1015 and from then on it seemed that every returning boat brought its load of wounded. The two Marine Divisions that landed abreast that day suffered seventeen hundred and fifty casualties before the next morning.

"What was ensuing ashore can be garnered in part from the reports of the individual Battalion Surgeons. Much however must be read between the lines as the heroic sacrifices which characterized the performance of the troops and medical units alike is seldom brought out in official documents.

"The Sixth and Eighth Regiments landed abreast with two battalions of each regiment in the initial assault. Company aid men landed with their respective platoons, whether in the first wave or the succeeding ones. The Battalion aid sections landed uniformly in the fourth and fifth waves. Collecting Sections were scheduled to land in the first waves of the second trip of the amphibian tractors and landed at approximately H plus 90 minutes.

"Excerpts from the records relate the highlights of the first few days. From the Second Battalion, Sixth Marines: 'Medical Section landed in the fourth and fifth waves on Red Beach at H plus 21 minutes. Battalion Surgeon, Lt. D. J. Volpe (MC) USN, was hit by a mortar shell in the first ten minutes. The aid station was set up on the beach and wounded treated where they fell and evacuated in amphibian tractors. Bandsmen attached as litter bearers did a magnificent job. Supplies were adequate with the exception of litters. There were two hospital corpsmen killed and ten wounded the first 24 hours. Pharmacist's Mate third class Robbins was killed on D-night while manning a machine gun in his company.'

"From the Third Battalion, Sixth Marines: 'Corpsmen with "I" company landed in the first wave at 0830, corpsmen with "K" and "L" Companies landed in the second and third waves respectively. The battalion aid section landed at H plus 20 minutes and set up in Japanese trenches on the beach. Forced to move as artillery made direct hit on an amphibious tractor, setting it afire and making the position untenable. At

1500 moved inland about two hundred yards and set up in Japanese dugout near battalion command post. Shortage of litters developed and some wounded were evacuated in ponchos. There were two corpsmen killed in action and eight wounded the first day. On the morning of D plus 2, the battalion bore the brunt of a Nip tank attack, knocking out twenty-nine enemy tanks. One corpsmen was killed and three wounded during this encounter.'

"The second and third battalions of the Eighth Regiment landed almost one thousand yards to the north of their intended area. When Eighth Regimental Headquarters landed at H plus 60 minutes, the entire section including the Regimental aid group, landed on a beach with no troops in front of them. Casualties were extremely heavy and the Regimental medical section functioned in the capacity of a battalion aid station until the two assault battalions could be maneuvered into their proper position. The second battalion of the Eighth suffered heavy casualties to the medical section when an artillery shell landed in the aid station, killing one corpsman, seriously wounded the Battalion Surgeon and three corpsmen.

"The Collecting sections assigned to the assault battalions served as both aid stations and evacuation stations for the first two days due to the heavy casualties in the immediate beach area. Shore party medical sections and Navy Beach Party medical sections were committed uniformly on D plus 1 and when these sections assumed the evacuation station responsibility, Collecting Sections moved forward to work in close conjunction with battalion aid stations. They were returned to their respective medical companies on about the sixth day by which time adequate ambulance transportation was available almost to the front lines.

"Meanwhile, the medical companies were working unceasingly on the transports to assist the ship's medical department in the care of casualties. Enemy fire on the beaches was so intense that it was impractical to land them and establish facilities ashore. On D plus 1 reconnaissance revealed a Japanese civilian hospital in the Charan Konoa area on the right flank of the Division, miraculously unscathed by our pre-invasion bombardment. As evacuation at night was highly unsatisfactory due to smoke screens laid to protect the ships from enemy air attack, "C" and "E" medical companies were ordered ashore at 1200 on D plus 1 in order to provide some measure of definitive treatment to casualties during the hours of darkness. "E" medical company landed at 1700 but was forced to dig in immediately under heavy enemy shelling. "C" medical company landed at 0730 on D plus 2 and the two companies proceeded to the Japanese hospital and were in a position to do surgery by nightfall.

"On D plus 5, 'E' medical company was moved to the north to the junction of the major road network to act as a screening agency for all casualties as well as providing a surgical unit nearer the center of the zone of action for treatment of non-evacuables. They were replaced at the Charan Konoa by a fine surgical team from the Army which was assigned to the Division by the Fifth Phib Corps.

"No records are available for the first two days of the casualties received at the Charan Konoa installation, but in the next seven days, 398 casualties were admitted with forty-six major surgical procedures performed. If one remembers that only casualties who could not be evacuated to ships at night were handled here, the immense importance of the early establishment of this hospital is more fully realized.

"A summary of the chain of evacuation at this stage follows: Initially, casualties were put in any amphibian tractor available by the nearest medical personnel. Aid stations and collecting sections established evacuation points on landing and on D-day plus 1, evacuation was consolidated through shore party medical sections. Regimental medical sections began to channel casualties through their installation on D plus 2. Beginning on the evening of D plus 2, all casualties occurring late in the evening or during the hours of darkness were evacuated to the medical companies at Charan Konoa. With the establishment of 'E' medical Company at the major road junction, all casualties, both day and night channelled through this installation. In daylight all casualties, capable of being further evacuated, were sent to ships and at night were either retained at 'E' medical company or sent to 'C' medical company in Charan Konoa.

"Casualty evacuation from the beach was undertaken in amphibian tractors, any tractor leaving the beach being utilized. The original plan called for one LST(H) off each division beachhead to act as a casualty clearing station to insure reasonable distribution of casualties among the transports. Due to changes in the designation of the vessels assigned to this task, the plan was not carried out and casualties were transferred to any LCVP available at the tractor transfer line. The LST(H) assigned to the Second Marine Division beachhead received its first 100 casualties while still in the transport area, 22,000 yards from the beach. When the 100 casualty mark had been reached this LST(H) came alongside the U.S.S. Monrovia and discharged all the casualties to that ship. As there were no hospital ships or other especially fitted vessels for casualty handling, the transports were the sole agency to care for the tremendous load of casualties which occurred the first three days.

"Although the doctors and corpsmen worked unceasingly, an analysis of the battle casualties in immediate need of definitive care as compared with facilities available will serve to show the overwhelming demands on the Medical Department afloat. Of the 1750 casualties that occurred the first day, it may be assumed that 20 per cent or 350 were either killed outright or beyond medical assistance. Forty per cent or 700 were relatively slightly wounded and not necessarily in need of immediate definitive care. The remaining forty per cent or 700 were the concern of the forces afloat. There were approximately 40 transports in the area available for casualty handling. This meant that even if an absolutely equal distribution of such cases could have been made, each transport would have had seventeen to eighteen casualties demanding major definitive care in the first twenty hours and the expectation of as many more for the next two or three days. Actually, with no distribution agency functioning, several of the APA's bore the brunt of the casualty load.

"Evacuation to the ships at night was extremely difficult, if not impossible in most cases, due to the smoke screen which fogged the transport area during air alerts. On D plus 3 the first hospital ship arrived and was immediately loaded with casualties which had accumulated. As our transports were forced to leave the area on D plus 2, due to threatened Japanese surface attacks, casualties from the Second Marine Division were channelled to those APA's supporting other organizations which increased the demands on those already overloaded ships.

"The medical department's participation in this operation can be divided into two phases. Due to the aforementioned withdrawal of our transports, the Division was unable to land much of its vital supplies and ammunition, and also three of the medical companies. These medical companies had not been ordered ashore until noon of D plus 2 as the tactical situation ashore would not permit their utilization. By the time the order for their landing reached them, it was too late for them to dis-embark and they accompanied the transports to sea, assisting in the care of the casualties already aboard. From a military standpoint, the Division was reduced to improving its local position until the transports returned and supplies could be built up for the further occupation of the island.

"The first phase, then, occurred from D-Day until D plus 6, during which time the evacuation policy was immediate except for nonevacuables and for those cases which needed immediate definitive care during the hours when evacuation to ships was impossible. The second phase began with the establishment of the division hospital ashore on D plus 7, at which time the extent of definitive care given to all casualties was governed by the capacity of the hospital and the rapidity of further evacuation to supporting hospital units ashore or afloat.

"Immediately on the return of the transports to the transport area off the Division Beach, "D" medical company and the Division Hospital, consisting of "A" and "B" medical companies, were landed. All three medical companies moved directly to the group of damaged buildings which had formerly housed the main Japanese radio installation. Although filled with debris and partially smashed by our pre-invasion bombardment, these buildings offered housing for a hospital installation which is seldom met with in battle.

"They were strategically located near the major road network, both to the front lines and the beach evacuation station. Built of reinforced concrete and surrounded by 15 feet of earth works, they offered a large measure of protection both from direct fire and from light artillery and bombs. With the able assistance of working details from the Sea

Bee's and Engineers, debris and damaged machinery were quickly cleared and over-head and bulkheads repaired.

"In one of the two buildings an overhead projected over one-third of the floor space and by securing blankets around the margin, black-out space was provided for six operating tables.

"On the night of D plus 7, 37 casualties were admitted and given definitive care as indicated. The second day 58 casualties and the third day, 159 were processed. As more space was cleared, further operating units were set up. Three surgical huts were utilized for cases which demanded the greatest degree of asepsis. The buildings themselves could comfortably house 300 patients and as the need arose, additional beds were set up in double storage tents around the main buildings. Deep trenches were dug by bulldozers for protection of the patients in case of air raid.

"On D plus 11, 'C' medical company was moved to this installation. Although the total bed capacity of four medical companies is set at 576 beds, by pooling our various facilities, this reinforced Division Hospital was able to accommodate almost twice that number of sick and wounded. In the majority of instances, to maintain a casualty census of this size in the division zone of action would not be good practice; however, the Division had another operation to undertake immediately following the Saipan Campaign and the guiding principle was to save every man from further evacuation who could be kept in the Division and readied for this second assault.

"The statistics for the campaign reveal that 3,612 of the 5,156 admissions to the Medical Companies were returned to duty in time for the Tinian operation which occurred two weeks after Saipan was officially declared secured.

"The Division Hospital installation occupied an advantageous position. A good road network fanned out to all front line units and although the distance to the front increased to as much as five miles before the battle ended, the many advantages of the initial installation outweighed the disadvantage of the longer ambulance haul. Evacuation to seaward was easily accomplished with the use of DUKW's, loading directly at the hospital and necessitating no transfers of personnel before they arrived aboard ship. Although the front lines were at times less than a mile forward, and occasional artillery and mortar fire fell in the area, no casualties were sustained from enemy fire. Snipers were active in swamps around Lake Susseppe, 400 yards to the East but were cleared out by the Division Reconnaissance Company after several days.

"Under the direction of the Medical Battalion Commander, the four medical companies were molded into an approximation of an Evacuation Hospital. A central admission and triage ward was set up which distributed casualties according to type to the various surgical teams set up for each specialty. 'C' Medical Company set up four hundred beds to accommodate the routine sick, mostly dysentery, dengue, and recurrent malaria. 'E' Medical Company admitted all the chest and eye cases, and 'A' and 'B' Medical Companies took the Orthopedic and Abdominal cases. Minor wounded were distributed among all four companies, depending on the bed capacity at the moment.

"Centralization of the service elements of the four companies relieved the medical officers of a great many of the details of administration. Supply, messing, guard detail, transportation, and sanitation were all handled by Headquarters and Service Company of the Battalion. The direction of the combined mess by Lt. John J. Schneider (DC) USNR, was especially noteworthy. This officer procured fresh food from the transports daily and with the aid of fifteen colored messmen secured from Division Headquarters, served twelve hundred hot meals three times a day. By screening a damaged frame building to the rear of the main hospital, an excellent galley, completely fly proof, was put in operation on D plus 9 and the hot meals thus available undoubtedly played a large part in the early return to duty of the minor wounded, sick and exhausted patients.

"During this period, we had three cardinal aims in mind:

a. Hospitalization of those who would eventually return to duty within 30 days.

b. Hospitalization and treatment of nonevacuables, until their condition improved sufficiently to allow their safe evacuation by air or to hospital ships.

c. Definitive treatment of those where earliest possible care was necessary to give them the best chance of recovery.

"The chart below gives the breakdown of the number, type, and disposition of casualties admitted. Brief reports of the various teams handling special types of casualties, though incomplete, shed some light on the work done at this installation. There were a total of 266 compound fractures classified as follows:

Leg	54
Pelvis	5
Patella	5
Skull	8
Mandible	6
Scapula	8
Clavicle	3
Foot	15
Maxilla	7
Spine	7
Femur	47
Humerus	44
Forearm	29
Hand	26
Ribs	2

STATISTICAL REPORT—SECOND MARINE DIVISION HOSPITAL

Type of Injury	Number	Pent. Sod.	Ether	Spinal	Operative	Cast	Ship	Air	Duty	Deaths
Intracranial	34	2	0	0	7	0	12	5	6	11
Chest (Intrathoracic)	72	0	0	0	6	0	51	7	0	14
Abdominal	51	0	12	13	22	0	41	4	0	6
Chest & Abdomen	13	0	2	2	4	0	6	0	0	7
Spinal Cord	12	1	4	0	5	0	3	7	0	2
Extremities	1031	176	1	0	122	208	488	136	399	8
Eye	59	4	0	0	9	0	20	12	27	0
Abdomen & Extre.	14	1	2	1	4	0	10	0	0	4
Chest & Extre.	17	4	0	0	3	1	16	0	0	1
Chest & Spine	3	0	0	0	2	0	2	1	0	0
Chest, Spine & Abdominal	1	0	1	0	1	0	1	0	0	0
Shrapnel, Mult.	164	13	0	0	11	1	61	23	78	2
Miscellaneous Wounded	617	32	1	0	32	0	132	20	464	1
Disease, Combat Fatigue & Non-battle Casualties	2466	0	0	0	0	0	97	57	2312	0
TOTAL	4554	233	23	16	228	210	940	272	3286	56

NOTE 1.—The above breakdown of injuries does not include the 398 cases admitted to C Med. early in the campaign before they became attached to the Division Hospital. Of these, 160 were evacuated to ships; 122 returned to duty and 101 left with the Fifth Corps Medical Battalion who relieved C. Medical Company at Charon Konoa.

NOTE 2.—There is a discrepancy of 204 between total admission from the daily admission records and the above breakdown report of admissions. This is partly explained by the fact that many Marines with minor wounds came in for treatment and then without authorization left the hospital to get back to their organization on the front lines before any write-up could be made of their case.

NOTE 3.—No record was kept of the number of local anaesthesia employed. Suffice to say that local anaesthesia was used in all debridements where a general was not employed.

One hundred and twenty four (124) casts were applied and fifteen (15) amputations performed in this series.

"In a series of forty one (41) abdominal wounds seen by the chief of abdominal surgery, twenty one (21) were operated, with a mortality of twenty eight (28) per cent. The remaining were able to be evacuated immediately to a hospital ship or were complicated by other multiple wounds and their condition precluded surgery.

"The importance of an eye surgeon is demonstrated by the following report of his activities, many of the cases being from other organizations. Only fifty nine (59) cases were classified in the breakdown as eye injuries. Altogether there were one hundred and twelve (112) eye cases, but fifty three (53) were carried under other diagnosis; the eye injuries being complicating injuries. Of the one hundred and twelve cases, twenty two were in need of immediate major eye surgical treatment, for the following reasons:

a. Penetrating injuries of the cornia with foreign bodies and iris inclusions.

b. Destructive injuries to lids and orbital tissue involving extra-occular muscles and adjacent structures; debridement, control of hemorrhage and initial antiseptic treatment given.

c. Penetrating wounds of the sclera, where initial suturing prevented loss of vitreous.

d. Evisceration of remnants of the eyeball.

"Eighteen patients with retinal detachment were received. Those cases were diagnosed only because an experienced ophthalmolgist was available. Five cases of intraoccular foreign bodies visible with an ophthalmoscope and eighteen cases of intraoccular foreign bodies demonstrable by X-ray were seen in this group of cases. All these cases were promptly evacuated. Thirty cases had corneal injury of such severity that initial cleansing, removing of foreign bodies and cycloplegia were indicated as prompt measures to prevent secondary involvement in the same eye and sympathetic involvement of the other eye.

"The remaining twenty-nine cases represented a miscellaneous group of battle injuries including burns, which definitely needed the judgment of an experienced ophthalmologist for their initial care and disposition.

"It must be realized that pooling of medical companies in this manner can not be done where the lines of evacuation are prolonged or where the road network does not converge as occurred in this instance. The effectiveness of this installation, however, was the basis for the reorganization of the medical battalion now adopted, whereby the medical companies supporting the regiments are stripped down to a maximum of sixty beds and the majority of the medical service of the division concentrated in two hospital companies where all the specialties can be represented.

"So far the discussion of the second phase has been concerned with the activities of the Medical Companies. During this phase the attack was being pressed forward and violent fighting was continuous until the island was secured. Doctors and Corpsmen with the front line elements, without exception, bore up under this ordeal and added many a chapter to the fine record of performances of the Field Medical Service. The Battalion Medical Section of the 1st Battalion, 29th Regiment, attached to the Division for this operation suffered 27 battle casualties out of a complement of 40. Both Medical Officers were wounded; Lt. Charles M. Grace (MC) USN remained on duty with minor shrapnel wounds, and Lt. Edward Munns (MC) USNR remained on duty for eight hours until relieved although he had a shrapnel slug deeply imbedded in the muscles of his back. Lt. Comdr. Israel S. Zindberg (MC) USNR and his corpsman, with the Battalion Aid Station of the Third Artillery Battalion stayed at their posts, although their unit was completely overrun in a banzai attack. Lt. Comdr. Zindberg commandeered an Army tank and went with it to evacuate wounded on the field.

"Three Navy Crosses were awarded to members of the section for that day's work, two posthumously. Lt. Comdr. Manio (MC) USNR, with an advanced echelon of his medical company, was overrun in the same banzai attack of 4,000 Japanese. By cool leadership, he maintained order among his corpsmen, withdrawing into a secluded ravine and due to this action not one corpsman or patient received a wound from enemy fire. The Battalion Aid Section of the Third Battalion, Sixth Marines while a part of the perimeter defense of the Battalion Command post, sustained the brunt of a

banzai charge of over 100 Japanese soldiers. By cool and well directed fire they were able to contain the attack until other elements could be organized to exterminate the enemy. These were but a few of the highlights which were the daily fare of all front line units. A note of unintentional but grim humor enters the report of one Battalion: 'At 0330 a lone Japanese slipped into the Aid Station and attacked a sleeping Corpsman with a saber, another corpsman shot and killed the Nip. The security watch was greatly increased!' "

CHAPTER 3

THE MEDICAL ASPECTS OF AMPHIBIOUS OPERATIONS IN THE MEDITERRANEAN*

GENERAL CONSIDERATIONS

The Mediterranean campaigns began with the Allied landings in French Morocco and Algeria on 8 November 1942 and continued through the North African campaign, the Sicilian campaign, the Italian campaign and the Southern France campaign to the final downfall of Nazi Germany on 8 May 1945. The North African campaign was the first in the series and for that reason probably the most important because it established the pattern for those that followed. The stakes were control of the southern shores of the Mediterranean, from Gibraltar to Suez, which afforded a base of operations against the continent of Europe. It involved the defeat of the enemy in an area which he was in a better position, strategically, to defend than the Allies were to attack. A defeat for the Allies at that particular time would not only have lost valuable forces and equipment but would have dealt Allied morale and prestige a severe blow and undoubtedly would have prolonged the European war indefinitely.

The North African campaign ended in May 1943 with the destruction of the German-Italian forces in Tunisia. It was quickly followed by the invasion and capture of Sicily, and this in turn by the Salerno landings on the Italian mainland. The islands of Sardinia, Corsica, and Elba were captured by Allied forces during the course of the difficult Italian campaign. On 15 August 1944, two months and nine days after the Normandy invasion, American, British, and French forces from bases in North Africa, Southern Italy, Sicily, and Corsica landed on the coast of Southern France to add their support in the final campaign against the European Axis forces.

All the campaigns in the Mediterranean Theater of Operations were combined operations, involving land, naval and air forces of the United States and Great Britain, under a Supreme Allied Commander. In the command arrangement promulgated by the Combined Chiefs of Staff the second command echelon, under the Supreme Allied Commander, contained the commanders of the land, naval and air forces, respectively. The naval commander in this echelon was the Commander in Chief of the Royal Navy Mediterranean Fleet. The senior U. S. naval commander in the theater was in the third command echelon. French Army, Navy, and Air Units were reorganized and rehabilitated with lend-lease equipment and joined the Allied Forces as soon as they were brought to an effective operational level.

After the conclusion of the Armistice with the French in North Africa the U. S. Navy proceeded immediately to establish a series of bases on the Atlantic coast of French Morocco and the Mediterranean coast of Algeria. The former were primarily for the purpose of expediting the landing of the build-up forces and for the protection of the convoys concerned therewith; the latter were amphibious force bases for offensive action against the enemy. The establishment and early administration of these new bases were accomplished without a central directing naval authority in the theater and

* As prepared by Capt. F. C. Greaves (MC) USN.

this arrangement was continued until the early spring of 1943 at which time a new command, the U. S. Naval Forces, Northwest African Waters, was organized. The commander of these U. S. Naval Forces, Vice Admiral H. K. Hewitt, USN, established his headquarters ashore in Algiers as an integral part of Allied Force Headquarters, in March 1943, and perfected the organization and administration which continued throughout the Mediterranean campaigns. U. S. Naval Headquarters was moved to Naples, Italy, in June 1944 when AFHQ moved forward to Naples and Caserta.

The mission of the U. S. Navy, in cooperation with the Royal Navy, was primarily that of organizing and prosecuting amphibious operations against the enemy. Additional missions were destruction of enemy naval forces and shipping in the Mediterranean and its approaches, the protection of Allied sea-borne shipping and the furnishing of naval gunfire support to military operations ashore. The U. S. Navy was assigned the major portion of the primary mission by the Combined Chiefs of Staff with the allocations of essential landing craft and materiel, hence the organization and administration of the United States naval forces in the theater were influenced by the necessity of maintaining and operating the amphibious forces and bases at the highest practicable level of efficiency.

An advanced Amphibious Training Base was established at Arsew, Algeria, immediately after the November 1942 landing and satellite bases were set up at Namours, Beni Saf, Mostaganem, Tenes, and Cherchell, all in Algeria, between Spanish Morocco and Algiers. After the capture of Tunisia, additional amphibious training bases were established at Karouba and La Pecherie, near Bizerte, at Ferryville and at La Goulette, near Tunis, and the satellite bases in Algeria were progressively depleted and finally disestablished. As the war moved into Sicily and Italy new amphibious training bases kept pace, the last being set up in Salerno and Pozzuoli, Italy. Two naval operating bases, Casa Blanca and Oran, were organized immediately after the Armistice. Two satellite bases to Casa Blanca, at Fedalla and Safi, were set up at the same time but after a few weeks operation they were found to be unnecessary as ports of entry and were disestablished. The Port of Oran very early became the most important in the theater and continued to enjoy this distinction until the war moved into central and northern Italy after which Naples became the principal port of entry. The importance of the Oran Naval Operating Base paralleled the importance of the port and it served as the distributing point for all naval supplies and equipment in the theater, as did similar Army installations for that branch of the service. A third large naval base was established at Palermo, Sicily, where American Forces of the 7th Army captured a modern and well stocked shipyard, practically undamaged, which proved of great value to the Allies in the maintenance and repairs of their naval craft. The patrol torpedo boat squadrons operated from temporary, catch-as-catch-can bases along the eastern Algerian and Tunisian coast until the islands of Sardinia and Corsica were captured after which three bases were established at Madalena Island, Sardinia, and Calvi and Bastia, Corsica. A subsidiary base was set up in September 1944 at Golfe Juan on the French Riviera, near Antibes. Naval stations were set up in Toulon and Marseilles. The former was disestablished within a few months, as soon as the port of Marseilles was cleared of sunken and scuttled ships. A large naval air base was established at Port Lyautey, French Morocco, with a satellite base at Agadir immediately after the Allies landed in North Africa. A second subsidiary Air Base with lighter than air facilities was set up at Cuers, near Toulon, France, early in the fall of 1944. The Salvage Base at Dellys, Algeria, near Algiers was established in the late summer of 1943 and completes the list of bases from which the U. S. Navy operated during the Mediterranean campaigns.

The U. S. Naval Forces Afloat, except for those which were a part of the Amphibious Command, varied considerably at different times throughout the campaigns. There were always two or three divisions of destroyers, or parts of divisions, attached to the Command at all times, as well as two or more light cruisers, two headquarters ships, mine craft and service force ships. An increase of the number of ships occurred immediately before an operation. Additional cruisers and destroyers and many APA's, XAPA's and AKA's were present at these times. Capital ships and carriers for the Sicilian, Salerno and Anzio landings were furnished by the Royal Navy. The greatest concentration of naval power occurred immediately preceding and during the Southern France operation. U. S., British and French battleships, carriers and cruisers added their power to this undertaking. Only one

U. S. Navy hospital ship appeared in the Mediterranean during the campaigns. The *USS Refuge* made one shuttle trip between Oran and the U. S. A. in July 1944 and returned to take part in the Southern France operation, remaining in the theater one month.

ORGANIZATION OF THE NAVAL MEDICAL DEPARTMENT

The first contingents of U. S. Naval personnel to arrive in North Africa after the landings were the groups destined to set up the new bases. Each group contained a medical component of a variable number of medical officers and corpsmen and Medical Department equipment for dispensaries of sufficient size to serve the proposed bases. The equipment included Quonset huts for housing the dispensaries. In many cases permanent buildings in the cities where the new bases were established were requisitioned and found to be more suitable than Quonset huts and these were used for other purposes, or were left uncrated in the storerooms. No serious difficulties were experienced in acquiring quarters of suitable size by military requisition through the U. S. Army from the French Government. Such quarters were always deficient, however, in plumbing and electric lighting facilities, both of which utilities are usually sub-standard in most North African communities. It was usually possible to improve them by the substitution of American equipment and they eventually reached a point where they approached Navy Medical Department standards.

Dispensary facilities only were provided for the new bases. Cases requiring hospital care and treatment were transferred to the nearest U. S. Army hospital. As the U. S. Navy installations in the theater grew beyond the scope originally contemplated, particularly in and near Casa Blanca and Oran, it became obvious that U. S. Navy base hospital facilities were needed. The enlarged and overgrown dispensary in Casa Blanca was commissioned Base Hospital No. 5 in May 1943, and a 500 bed Quonset hut hospital was built at Oran and commissioned Base Hospital No. 9 in November 1943. These two hospitals served as the hospitalization centers for U. S. Navy personnel throughout the campaigns. Base Hospital No. 9 was particularly well located because of the lines of air, sea and rail communications connecting Oran with advanced areas to the east and the oversea lines of communication for the evacuation of patients back to the U. S. Base Hospital No. 5 was used principally for the hospitalization of personnel from the bases and naval groups in French Morocco. Its location permitted easy evacuation of patients by air to the United States by the Naval Air Transport Service and the Air Transport Command, from Port Lyautey and Casa Blanca, respectively.

The dispensaries which were established at the Naval Air Station, Port Lyautey and at the Naval Base, Palermo, Sicily were of adequate size, and had sufficient personnel and equipment to enable them to furnish hospital care for all types of patients. Both performed valuable and satisfactory work. The Port Lyautey dispensary was set up in one wing of the civilian Municipal Hospital, on a lease which assured occupancy until one year after hostilities ceased. It was located about 5 miles from the Base which was satisfactory until information was received that plans should be made for U. S. Navy occupancy of the base for an extended post-war period. A 100 bed Quonset hut dispensary with complete hospital facilities was constructed on the Base and upon its commissioning in January 1945 the lease with the civil authorities for the original dispensary was terminated. The Palermo dispensary was established in the residence of an Italian nobleman who had fled Sicily before American occupancy. The building was large and was easily converted into an excellent 150 bed hospital type dispensary. It continued to function as the only American military hospital in Sicily during the last year of its existence. It was disestablished at the time of the roll back program in the spring of 1945 when a small dockside sick bay-dispensary was set up for the care of the skeleton Navy crew that remained on duty.

The Advanced Amphibious Training Base at Arzew was supplied with a 100 bed dispensary which was set up in Quonset huts. It never became more than a dispensary because of the close proximity of many large Army hospitals and Base Hospital No. 9 within a radius of 25 miles. Excellent paved highways connected the Base with the city of Oran. It continued to be the central medical activity of the amphibious forces as long as the Arzew Base performed the same role. As soon as the Allied Forces gained military control of the Bizerte-Ferryville-Tunis triangle the main component of the amphibious force was moved forward into that

area. The new site was that of the French Naval Base at Karouba and La Pecherie and the medical department moved into the former French naval infirmaries which had been considerably battered by bombing attacks but which were rendered serviceable by repairs. Serious cases requiring hospitalization were transferred to near-by Army hospitals when the dispensary facilities were deemed inadequate to handle them. The subsidiary amphibious training bases maintained 25 bed dispensaries and confined the scope of their work to dispensary care using Army facilities for the treatment of conditions beyond that scope.

The forces afloat handled their patients in accordance with standard naval custom. The smaller ships transferred patients to larger ships or to shore establishments, using U. S. Navy facilities whenever possible, and when these were not present, U. S. Army, British Army or civilian hospitals. The larger ships, particularly the transports, were set up with excellent sick bays and were able to care for all type of cases and were of great assistance to the smaller ships and smaller bases.

The procurement of medical supplies was an extremely difficult problem for the U. S. Navy bases during the first few months of their existence. This was due primarily to a misunderstanding on the part of both the medical officers in the field and the Medical Supply Depot in Brooklyn in the matter of the allocation of shipping priorities into the theater. The Combined Chiefs of Staff had assigned control of all shipping into the theater to the U. S. Army Service of Supply (later the Service Command) and cargoes were loaded on the east coast in accordance with priorities assigned. Except for Navy cargoes loaded into U. S. Navy ships destined for assignment in the theater no Navy cargoes were loaded at east coast ports unless they were authorized by a priority approved by the Service of Supply. Medical Department requisitions were sent in regularly by the bases and were received, filled and transferred to the ports by the Naval Medical Supply Depot, just as regularly, but nothing happened beyond that stage. When stocks became dangerously low in the naval medical activities the medical officers went to the U. S. Army for help but were not always successful, particularly during the early months, because Army stock piles were none too adequate and the demands of their extended activities and the Tunisian campaign were tremendous. When it was discovered that nonshipment was due to a failure to establish shipping priorities and not to larceny on the part of merchant marine crews and stevedores the difficulty was quickly resolved by obtaining the necessary priorities. Navy Medical Storehouse No. 9 was set up in Casa Blanca and continued to operate from that point until it was transferred to Oran in the spring of 1944. Most of the routine medical supplies and equipment were obtained direct from the Storehouse after its establishment. A very appreciable amount of stores and equipment was obtained at various times and places from the U. S. Army on transfer of property vouchers. This was especially true immediately preceding operations and was due principally to the better availability of numerous Army Medical Supply Depots.

Cooperation between the Medical Departments of the Army and the Navy was quite satisfactory and improved steadily with continued association throughout all the Mediterranean campaigns. Mention has been made above of the attempts of naval medical activities to obtain needed medical supplies from Army Medical Depots and of the varying degrees of success experienced. This statement refers only to the first months of American occupation of North Africa. It occurred at a time when the Army was not well stocked with supplies and was in the midst of a tremendous expansion program. The Tunisian campaign was swinging into its crucial stages. There was no surplus of anything, including medical supplies, in the theater at that time. The high echelon of the Army Medical Department realized that the Army had been given logistic responsibilities in the theater and were endeavoring to meet them but the mechanics of the prolem had not been worked out at that time to the extent that they were sufficiently well known on the levels of the Medical Depots. No further difficulty or delay was experienced in obtaining needed supplies once the procedures became familiar to all hands in both services.

U. S. Army hospitals rendered a very considerable amount of medical care and treatment to the U. S. Navy personnel. This was in keeping with agreements reached before the invasion of North Africa by the planning staffs on the Combined Chiefs of Staff level. Later agreements supplementing the original plans continued the arrangement in the interest of avoiding duplication of logistic

efforts wherever possible. The arrangement was satisfactory and workable in its broader aspects but it presented problems requiring adjustment to circumstances in its details. Professionally, of course, there was no difference between the two services. The medical officers of both possessed the same background of basic and professional training before the war and were equally capable of handling the medical and surgical problems confronting them. The difficulties arose from the differences in the administrative procedures of the two services.

The Army employs a centralized system for its medical records. The individual's health record is retained in the Office of the Surgeon General, in Washington, and pertinent additions to it are added by forwarding them from the field. Thus, the activities in the field never have more than the current records to be concerned about. The Navy, on the other hand, uses a partly decentralized system wherein the health record is retained by the individual's medical officer and clinical record sheets are forwarded to the Bureau of Medicine and Surgery at specified times for inclusion in the individual's jacket. The descriptive sheet, the medical abstract, the immunization record and the dental record are retained in the health record. *Navy Regulations* places responsibility for the custody of health records with the individual's commanding officer and medical officer and provides for records of transfer when health records are transferred with individuals from one command to another.

When Navy personnel were transferred to Army hospitals the Army assumed responsibility for their medical care and treatment. They continued to be Navy personnel, however, and the Navy retained jurisdiction over their accountability and future actions. They were in the same status as Navy personnel ordered to report to an Army unit for temporary duty, on completion of which they are directed to return to their naval command or to proceed upon other duty assigned. They remain under Navy jurisdiction and are not "lost" from Navy records and rolls. Very great confusion existed during the first six months of the North African campaign in the matter of Navy patients sent to Army hospitals. Naval medical officers and commanding officers followed *Navy Regulations* when they transferred patients and sent all the records with them to the Army hospitals. The Army medical administrative staffs, not being familiar with Navy records, usually let them get adrift. No distinction was made for Navy patients in the matter of evacuations to the rear, or to the zone of the interior, and Navy patients, health records, pay accounts and service records were scattered all the way from Tunisia to the United States without any one, Army or Navy, knowing where they were. The Army was not in a position to do much about preventing the confusion. They were busy handling the sick and wounded of an expanding force engaged in active combat operations and had no time to re-educate their medical personnel in a system that would be applicable only to Navy personnel. The problem was solved, more or less successfully, by an agreement reached locally within the theater in which certain Army hospitals in each area were designated as the ones to which Navy personnel would be transferred and by assigning Navy medical personnel to those hospitals, in an additional duty status, with orders to assume custody of and maintain personnel records of Navy patients in their hospitals, to monitor their transfers to other hospitals and to report such transfers to the cognizant Navy commands. The whole matter was cleared up and simplified on a service wide basis by a joint Army-Navy directive issued in the spring of 1944. Once this administrative detail was cleared up the cooperation between the Medical Departments of the two services was completely harmonious, and it is believed, mutually beneficial.

A good example of the cooperation that existed occurred in the winter of 1943-1944. A U. S. Navy Medical Photographic unit arrived in the theater with orders to obtain kodachrome motion pictures of casualties from their first treatment until their disposition or transfer back to the United States. They arrived at a very inopportune time for obtaining pictures of Navy casualties, since the only ones that were occurring were those that resulted from bombing and strafing attacks on convoys at sea, operations that were obviously unsuited for such a study. The Army not only granted permission for the unit to work on the Italian front but expedited the arrangements whereby they were able to photograph a series of war injuries, from front line dressing stations, through the various hospitals to the rear and final evacuations, via hospital ship, from the theater. They repeated their studies on the Anzio front and were aboard one of two hospi-

tal ships that were bombed by enemy planes and were fortunate enough to obtain a recognizable photographic record of this breach of the Geneva Conventions regulations. The films they obtained are excellent teaching material and will have great historical value in the future. The activities of the Unit marked the first attempt to obtain a medical photographic record of this nature and the experience gained under actual operational conditions in the field and through the various stops in the evacuation chain was excellent training and may well be taken as a pattern for future activities of this nature.

THE ACTIVITIES OF THE NAVAL MEDICAL CORPS IN AMPHIBIOUS OPERATIONS

Three major amphibious operations occurred in the Mediterranean following the invasion of North Africa; the invasion of Sicily on 19 July 1943, the invasion of Italy at Salerno on 9 September 1943, and the invasion of Southern France on 15 August 1944. Several amphibious landings also occurred in support of these operations, including those at Anzio and the capture of the islands in the Tyrrhenian Sea. The Navy Medical Department's responsibilities in combined amphibious operations are:—

1. Furnishing medical care for all personnel of all services while embarked in U. S. Navy ships.

2. Furnishing seaward evacuation of all casualties from the assault areas until the Army becomes sufficiently established to treat, hold and evacuate in a routine manner.

The first responsibility was recognized as existing in all U. S. Navy ships and craft regardless of size, type or mission. The cooperation of embarked medical personnel from other services was encouraged but not made mandatory. It was believed that cooperation would be mutually beneficial, to the Navy and to the embarked service, if embarked medical personnel assisted in holding routine sick call, because in that way they would be able to maintain proper records in their routine manner. Ships' Medical Departments were indoctrinated in providing ample sick call time for all hands on board. The responsibility extended to the small craft whose personnel had been thoroughly indoctrinated in first aid procedures. The Navy's responsibility for medical care and treatment extended from the time personnel from other services came aboard at embarkation ports on friendly shores until they were landed in the target area.

Casualty evacuation is a chain of several links the first of which is the medical section of the Navy Beach Battalion on the invasion beaches. The other links in the chain are the ambulance boats running between the beaches and the transports and supply ships lying off-shore, the landing craft that run in close enough to the beaches to receive casualties directly aboard, the transports and hospital ships in which both definitive treatment and transportation are provided, and the military hospitals in the rear medical echelon.

The duties of the Navy Beach Battalions, including the medical sections, are difficult and arduous. They land in one of the first waves and perform their duties, frequently under fire, during the difficult and confusing period of overlapping Army and Navy jurisdiction. A clear cut assignment of the division of responsibilities and adequate training of the Army and Navy medical sections in their duties are essential for efficiency. The Army must assume responsibility for the care of casualties landward of the high water mark and for their transportation to the Navy Beach Battalion evacuation stations. The Navy must care for casualties in the evacuation stations and for their evacuation seaward. An evacuation record is very important. The system found to be most satisfactory in the Mediterranean Theater was for the Army to furnish the Navy with a list of all personnel brought by them to the Navy evacuation stations and for the Navy to use this as a check-off list for all seaward evacuations, adding the names of those to whom they initiated treatment and later evacuated. The checked-off lists were then forwarded to the Army Medical Section for their permanent records. The Navy Beach Master, as the representative of the Naval Task Force Commander, was in charge of all sea borne traffic coming into and leaving the beaches. He was directed to make use of all craft transporting troops, equipment and supplies from ship to shore for the evacuation of casualties from shore to ship, as needed. No attempt was made to evacuate casualties until after assault troops and equipment were landed, except personnel wounded in landing craft en route to the beaches. Personnel so wounded were never landed, except in emergencies of disabled landing craft, because ineffectives on an assault

beach are of no military value and increase the tasks of the beach parties by their presence. They were given first aid by the small boat crews, retained aboard and returned to the mother ships. Increased efficiency in casualty evacuation was noted in each succeeding operation as weaknesses and shortcomings were studied, evaluated and eliminated.

Small craft returning to the transports or hospital ships with casualties aboard transferred their patients either by litter hoist or by hoisting the ambulance boats to the rail and transferring the patients directly to the deck. The most expeditious method from a military standpoint was keeping one boat, usually a disabled one, permanently rigged for hoisting and having the ambulance boats with casualties come alongside and transfer their patients. This method was utilized as much as possible, when weather permitted, as a means of avoiding delay in the use of small craft for landing troops and equipment.

Landing Craft Tanks (LST's) were considered as available evacuation ships. An operating room was set up on the forward part of the tank deck of each one taking part in an operation, and personnel were placed aboard to enable them to evacuate all types of casualties. They are acceptable evacuation ships and meet the requirements for emergency evacuations when other facilities are not available. The Mediterranean is peculiar in that distances between friendly shores and target areas are short enough to permit quick turnaround times for hospital ships of moderate speed but are too long to make the use of LST's desirable for casualty evacuation. LST's being combat ships and unprotected by the Geneva Conventions must sail in convoy and are legitimate targets for enemy planes. Medical planning in the Mediterranean provided them with casualty evacuation facilities to be used in case of necessity but their routine use was limited to the evacuation of ambulatory cases. Transports acted as hospital ships as long as they remained in the target areas, receiving and caring for all types of cases. There were sufficient U. S. Army and British hospital ships to take over evacuation duties when the transports left.

In all three operations the Commander of the U. S. Naval Forces Northwest African Waters (later the 8th Fleet) was the Allied Naval Task Force Commander but the Royal Navy, under the Commander in Chief, Mediterranean Fleet, exercised operational control of all naval craft in the theater, except those actually in the combat area. This arrangement was found to be unsatisfactory during the Sicilian campaign, insofar as it affected hospital ships. It required the Army Commander ashore in Sicily, upon determining his need for hospital ships, to request them from C-in-C, Mediterranean, by radio dispatch. The request was relayed to the Principal Sea Transportation Officer who issued the sailing orders. The plan was awkward and cumbersome and tended to delay casualty evacuation. It was changed in later operations by placing all hospital ships, regardless of service or nationality, in a pool under the direct operational control of AFHQ. An automatic schedule of their sailings was set up for the first week of the operations during which time they arrived off designated beaches at sunrise, remained all day and departed before sunset. At the expiration of the automatic schedule they were sailed to the combat area by AFHQ, as needed, upon request of the Army Commander in the field.

Hospital ships were not taken into the combat areas on D-Day. They were not needed because there were sufficient hospital and evacuation facilities aboard the ships of the invasion fleets and there was nothing to be gained in having them exposed to enemy counter measures in the confusion of D-Day battles. They complied with the Geneva Conventions in every respect, including full lighting at night. For this reason they were not permitted to remain in the target areas after sunset when all other ships were darkened. Their protected status was respected for the most part by the enemy, except for three attacks, one of which was probably accidental but the other two were definitely deliberate.

Evacuation ships delivered casualties to military hospitals in the rear medical echelon in accordance with plans agreed upon by the various services before the operations. Prior to reaching debarkation ports the ships' medical officers prepared casualty reports in triplicate, giving the full name and rank or rate of each casualty aboard, his service number and organization, the time and date received aboard and the date disembarked, diagnosis, treatment received while aboard and condition at time of debarkation (favorable, unfavorable, serious or critical). The originals of these reports

were mailed to the Detachment of Patients, U. S. Army, upon reaching the debarkation port. One copy was sent to the Commander, 8th Fleet, and one copy retained in the ship's files. U. S. Army casualties were not reported to the War or Navy Departments. Navy casualties, including deaths, were reported to the cognizant Navy Department divisions in accordance with article 908, Navy Regulations. Dead in ships in the combat area were taken ashore as soon as possible for burial by the Graves Registration Service. Dead in ships at sea were retained aboard, if practicable, for burial ashore; if not practicable, they were buried at sea, with an accurate report of complete identification, time and place of burial being forwarded to the Commander 8th Fleet.

MEDICAL AND EPIDEMIOLOGICAL CONSIDERATIONS

The Medical Department is charged with the responsibility of treating the sick and wounded in a military operation. It has a second responsibility of equal or greater importance, that of preventing disease. Modern warfare demands an unusual degree of physical and mental stamina. The success or failure of an operation may depend upon the physical ability and mental alertness of the forces engaged to carry on in spite of hardships and privations. The personnel comprising the armies and navies in war are frequently compelled to live under conditions which tend to undermine health. They are introduced into strange climates and crowded together in camps, barracks and ships where disease propagation is tremendously enhanced. Their routine habits of eating, sleeping and relaxation are dependent upon the exigencies of the campaign and may of necessity be entirely inacceptable from the standpoint of ideal hygiene. Added to these are the psychological effects of worry about self and family, fear, apprehension and the boredom of waiting for things to happen. It is the responsibility of the Medical Department to accept these conditions and prevent their becoming serious handicaps to the success of the operation and "to keep as many men at as many guns as many days as possible." The North African campaign established the pattern for all the operations in the Mediterranean Theater of Operations. It introduced untried men and new weapons to actual combat with a powerful and resourceful enemy from which they emerged victorious veterans. It confronted the Medical Department with the actual problem of coping with its responsibilities in a combat area.

The invasion of North Africa was made without the consent or prior knowledge of the Vichy French Government whose loyalty could not be depended upon. It was earnestly hoped that the French would not resist the landing but the desire for this state of affairs was not permitted to affect the plan to launch the campaign and prosecute it to a successful conclusion. It was realized that officers with pro-Nazi leanings might be in control of some of the French garrisons in the territory but it was believed that they would not be able to maintain a determined or prolonged resistance. As it happened some resistance was encountered, particularly in French Morocco, but it was not prolonged and pro-Allied influence soon gained complete control and an armistice was concluded between the Allies and the French. Liaison was immediately established with the French authorities, including those of the Public Health services, and a clear picture of health and sanitary conditions in the area was forthcoming.

There is a certain amount of misconception, particularly among the Americans, about the climate, the living conditions and the diseases which are present in French North Africa. There is nothing tropical or sub-tropical about the area. No part of French North Africa lies farther south in latitude than Central Florida or Galveston, Texas, and its Mediterranean coast is in the same latitude, approximately, as that of Washington, D. C., and Norfolk, Virginia. Its climate, topography and vegetation closely resembles that of Southern California. Rains occur in moderation during the winter months at which time snow and freezing temperatures may be experienced in the highlands of the Atlas mountains. Rainfall rarely occurs during the spring, summer and autumn months and irrigation is required for the extensive agriculture industry. Water for irrigation is obtained from projects built by the government and from community and private wells, some of which are equipped with modern machinery while others operate in as primitive a fashion as they did in the days of Rome and Carthage.

The French began extending their control over the region more than one hundred years ago and their influence on the public health and sanitary

standards is quite apparent, particularly, in the coastal region where the larger cities and towns compare with those in France itself. An excellent system of paved highways has been constructed in the populous coastal and agricultural districts. The larger cities have excellently administered Pasteur Institutes and organized Departments of Health can be found in all communities where the Europeans form an appreciable part of the population. Sewage is disposed of in a sanitary manner, the public water supply is safe to drink, food distribution is controlled by sanitary regulations and contagious diseases are isolated or quarantined. Modern hospitals are present and the practice of the medical arts is on a relatively high professional and ethical plane.

These evidences of sanitation and health control which are accepted as routine by the European component of the population are not so noticeable in the Arab communities. In many they are entirely absent. The Arabs, except for a very small minority who are wealthy and who have had contact with France and the rest of the world, exist very much as their ancestors had done for the past thousand years. They live in poverty, filth and squalor and infestation by lice is almost universal among them. Malaria, tuberculosis and the venereal diseases are widespread, infant mortality is high and the gastro-intestinal infections are endemic. French colonial policy has had little effect in improving their standards of living, since they are based upon racial customs and religious beliefs, and no official attempt is made to force education upon the Arabs, or to interfere with their age old habits.

Sicily and Southern Italy resemble each other in most respects. Both were well known before the war as vacation spots and both have long been popular with those interested in the arts and literature. The centers of the tourist trade and the artists colonies were sufficiently well sanitated to make life and health reasonably safe for those frequenting them and the homes of the upper and upper-middle classes residing there were also reasonably safe. A certain amount of sanitary improvement was copied by the lower classes and as a result the general trend of public health was upward before the war.

The overwhelming majority of Sicilians and Southern Italians, however, are definitely lower class and peasants. They are poorly educated, hopelessly poverty stricken and bound to the soil, or to their menial jobs, by tradition and custom and they barely manage to eke out a precarious existence for themselves and their large families. They live in poor hovels in the rural districts and in the slums of the cities and towns. Typhoid fever, the dysenteries and other water-borne infections are endemic. Malaria is widespread in the rural areas. The incidence of malnutrition, tuberculosis, skin disease, infant mortality and venereal disease is appallingly high. The Fascist Government seriously attempted to raise the standard of living for this underprivileged majority during the first few years of its regime but it is doubtful if any appreciable improvement resulted.

The average peasant in Sicily and Southern Italy is not particularly energetic. He lacks initiative and exhibits no apparent desire to better his conditions. He hopes to emigrate to the United States where he can make enough money in a few years to return to his native community and live out his life without further work or effort. He promptly dismisses all ideas of bettering his condition in his present surroundings as being totally impossible because of customs and traditions.

This was the local situation upon which the fury of modern warfare was visited in the invasions of Sicily and Southern Italy. Every strategic town and city which the enemy attempted to defend was badly damaged or obliterated. Utilities were seriously crippled or completely destroyed. Transportation was disrupted and the normal flow of foodstuffs from the rural areas ceased. Civil law and order all but disappeared, famine threatened all the civil populations and black markets of the most reprehensible and filthy types offered the only source of the necessities of life. Survival of the fittest became the law of the land and the very young and the very old and infirm suffered first and most severely.

The heavy and continual bombing drove the harassed people into whatever shelters they could find. They crowded together like sheep in the ricoveros built before the war and in the many caves and caverns that exist in the region. Their plight was particularly acute in Naples, the largest center of population in the theatre to be subjected to such punishing treatment. Naples was severely damaged. Whole blocks of tenements adjoining the water front, the marshalling yards and the air

fields were leveled. The people living in these parts of the city were the poorer classes and a large majority of them have probably always been infested by lice. Under the conditions of overcrowding in the ricoveros lousiness became universal. Typhus appeared among them in November 1943 and an alarming sharp upswing in the incidence of the disease was immediately apparent. Had it not been for the heroic and untried use of DDT in a program in which approximately two million persons were dusted one or more times within the short space of a few weeks a major public health catastrophe would have resulted. While the Italians did nothing materially to prevent the spread of the disease, it must be said in their favor that they cooperated in the dusting program in a docile manner and made no effort to obstruct it in any way.

The farther one moves northward up the Italian peninsula the higher the standard of living and the better the sanitation one encounters. Rome immediately before the war was undoubtedly the equal of any city in the world for modern sanitation and improvements. The Fascist Government spent millions of lira bringing it to that state. Mussolini boasted, and probably truthfully, that Rome had no slums. Modern apartments were built in all parts of the city and they housed all classes of the population. The city escaped the ravages of war, partly because of its religious importance as the center of the Catholic world and partly because of its historical and cultural treasures. The enemy chose not to defend it. Aside from precision bombing of the marshalling yards and the air fields in and near the city and one mysterious minor bombing incident in Vatican City the city suffered no damage.

Northern Italy is highly industrialized and its standards of living and sanitation are much more modern and satisfactory than those of Southern Italy. Malaria is endemic in the rural areas as it is throughout all the Mediterranean countries but it was kept in check before the war by intelligently administered controls. The same may be said for the gastro-intestinal infections. Public health control measures kept them down before the war but the war-induced displacement of populations and the attending hardships permitted them to undergo a sharp rise in incidence and create a health menace to the military forces.

Modern France was a well sanitated country before the war. All classes of society except the very lowest were more or less indoctrinated in and demanded modern sanitation. That part of France bordering on the Mediterranean has always had areas where malaria was endemic but it did not constitute a serious or threatening problem. Marseilles was notorious for its high venereal rate and its thousands of registered prostitutes. Certain districts of the city were slums of the worst type where any form of disease was apt to make its appearance and frequently did. The Germans made one of their characteristic attempts to eradicate some of the worst ones by removing all the inhabitants and leveling the areas. No doubt, the main reason behind their actions was to eliminate troublesome centers of resistance but the results also eliminated health hazards at the same time. The French Riviera and the Cote D'Azur, extending to the eastward from Marseilles to the Italian border, with Cannes, Nice, Villefrance, Antibes and numerous smaller towns and villages in this playground of Europe presented no problems in sanitation other than those directed against water borne and food borne infections.

Typhoid is prevalent the year around in and near Marseilles, about 60 new cases being reported each month during the summer season and somewhat less than that number during the winter months. The Public Health officials have determined that the infections result from eating shellfish taken from beds contaminated by raw sewage. There is some Malta Fever, caused by drinking of unpasteurized goat's milk from herds that range along the Durance River north and west of the city. Fievre Boutenneuse is also prevalent and is transmitted by the Ornithodorus tick. The soil of Southern France is heavily contaminated with tetanus spores and human cases of the disease are not uncommon. Marseilles reported the following communicable diseases for the period from 1 June to 15 September, 1944:

Typhoid	165 cases.
Diphtheria	69 cases.
Scarlet fever	23 cases.
Measles	13 cases.
Undulant fever	7 cases.
Tetanus	6 cases.
Cerebral meningitis	2 cases.
Tracoma	2 cases.
Leprosy	1 case.

Malaria is endemic in the islands of Sardinia and Corsica. These islands were occupied after the capture of Sicily and were used as bases in support of both the Italian and Southern France campaigns. The population of Sardinia is largely Italian but there is not the overcrowding which is so noticeable in Sicily and South Italy. Corsica is a French colony whose people are a mixed race and who are quite refractory to governmental control. The island is very mountainous and the mountain recesses have many bandits who recognize no authority. Malaria, typhoid and the dysenteric diseases constitute the main hazards to health in both islands.

MALARIA

The first objective for the U. S. Navy in North Africa, after the landings had been successfully accomplished, was the establishment of suitable port facilities through which men and equipment could be funneled into the new theater of operations for the consolidation of the initial successes and the prosecution of the contemplated campaign. Casa Blanca, Oran and Algiers were primary objectives and were captured in the initial landings. Their excellent port facilities were found to be largely undamaged and were taken over immediately and put to use as debarkation ports for the build-up forces.

The second objective for the U. S. Navy was the establishment of naval bases from which the naval and air operations against the enemy could be prosecuted. A naval air base was established at Port Lyautey, French Morocco, with a subsidiary air base at Agadir, French Morocco. Port Lyautey, located approximately 90 miles north of Casa Blanca, was the site of a French naval air base and was ideally situated for naval air operations against enemy submarines. It was immediately taken over by the U. S. Navy and a U. S. Naval Air Base established. It is located eight miles upstream from the mouth of the Sebou River which at this point is a slow flowing, meandering stream, approximately 100 yards in width and deep enough to permit the passage of small ocean-going craft. Its importance lies in the fact that the Sebou River offers the only site in the whole colony with a protected landing for seaplanes. One of the first bits of epidemiological information gained from the French was that the area surrounding the city of Port Lyautey and the air base had the reputation of being the most malarious spot in all French North Africa.

This information was amply substantiated by data available in the French naval base files. Forty percent of the French personnel at the base had the disease during the year immediately preceding American occupation. The incidence in the city of Port Lyautey and the surrounding countryside was equally high. It was reported that the French had seriously considered curtailing the activities of the base, or abandoning it entirely, because of its unhealthfulness, but had not done so because of the onset of the war and the lack of a substitute site in the area.

A survey conducted by a U. S. Navy Malaria Control Unit provided important information upon which a control program would have to be based. The river overflows its banks in a swampy area adjoining the air base and city annually and the residual water remains until it finally evaporates in the late spring and summer. The base itself occupies slightly higher ground and on the side away from the river adjoins grazing land with scattered collections of Arab huts. A fresh water lagoon is located 4 miles downstream from the base. Dippings from the lagoon, from stagnant water in the swampy area and from quiet pools in the river revealed many mosquito larvae, including anopheles, culex and aedes types. All the Arab huts within 5 miles of the base and many of the dwellings of the Europeans living near the base were found to be infested with adult anopheles maculopennis and culiciform mosquitoes. Spleen rates among the Arabs were 90% for the children and 50% for the adults. Blood smears made on both Arabs and Europeans living in the area showed a high rate of parasitization, predominantly benign tertian, but with a significantly high aestivo-autumnal number. Case histories of persons who had had the disease, clinically, showed a high percentage of recurring attacks, a characteristic feature of benign tertian malaria.

The French had attempted to control the disease and lower its incidence but had not been successful. A project started before the war had included drainage of the swampy area and construction of dams and canals as part of a plan to increase irrigation and hydro-electric power production. An extensive system of drainage ditches had been constructed on and about the base and a start

had been made in a program to dust the lagoon with Paris green from low flying planes. Anti-malarial drugs were made available to the Arab and European civilian population during the malaria season between 1 June and 1 November in an attempt to reduce the reservoir of infection. This part of the program met with the least success because of the Arabs who constituted the principal danger from infection and who could not be made to cooperate when the program conflicted with their racial customs and religious beliefs. Very little progress was made in lowering the morbidity rate and all centralized and coordinated efforts ended with the fall of France in 1940.

The estimate of the situation at the time of American occupation indicated that malaria constituted a real threat to the mission of the newly established Naval Air Base and that positive and vigorous control measures were necessary. A rather complicated condition of overlapping spheres of influence existed. The U. S. Navy operated and administered the base under the U. S. naval commander in the theater, who in turn was subordinate to the Commander in Chief of the British Mediterranean Fleet. It was an Army Theater under the command of the Supreme Allied Commander. The French Army and Navy were also a factor to be considered because every effort was being made to rehabilitate their forces and this was being done in the garrisons and bases which they had controlled before the invasion. Cooperation was required between these different groups but the important thing was to inaugurate a control program with a minimum of delay. The U. S. Navy indicated its desire and ability to assume full responsibility of protecting all personnel stationed on the base.

Fortunately, time was a factor that operated on the side of the control program. The occupation of the base occurred shortly after the end of the 1942 malaria season and several months would elapse before the 1943 season would begin. A Malaria Control Team, composed of a Malaria Control Unit and a group of approximately fifty Construction Battalion officers and men, was organized and given the task of rendering the base reasonably safe from malaria. Drainage ditches that had fallen into disrepair were cleared of vegetation and all collections of water which could not be drained immediately or readily were oiled at regular intervals. Screens were installed on the windows and doors of all living spaces and the use of mosquito nets was made mandatory for all hands. Officers and men were thoroughly indoctrinated in malaria discipline and carelessness and deliberate breaches were immediately punished. Liberty was made to expire for all hands at sundown and everyone working in the open or in unscreened buildings after dark was required to use mosquito repellents. Freon-pyrethrium was sprayed in all living and sleeping quarters daily to kill adult mosquitoes.

Attention was given to the dangers that existed in the town and surrounding countryside. An extensive system of new drainage ditches was constructed in the swampy area at a distance from the base. The lagoon was dusted regularly with Paris green from low-flying planes and later with DDT when this agent became available. The French and Arab inhabitants living nearby objected to this on the grounds that it was injurious to their livestock but their objections were overruled in the interest of the war effort.

The reservoir of infection that existed in the civilian population was not ignored. Atabrine was made available for use by both Europeans and Arabs but difficulties were encountered immediately with the latter. They could not be depended upon to treat themselves and they would not cooperate by coming to a central dispensing point or with the medical officers and corpsmen who attempted to prescribe the drug for them in their huts. They would not permit members of the control team to enter their homes to kill adult mosquitoes. That was strictly against their religion and, since suitable women in sufficient numbers capable of performing these tasks were not available, the obstacle proved to be unsurmountable and this part of the project was abandoned. As a substitute the Arabs were re-located in new huts beyond the probable flying range of mosquitoes and the old huts destroyed. The European elements of the population cooperated very satisfactorily with the program.

The U. S. and British Armies made the suppressive use of atabrine mandatory for all their forces in the North African Theater from mid-April to mid-November. The U. S. Navy did not adopt this policy but elected to depend upon mosquito control measures until such time as they were shown to

be inadequate. The Port Lyautey area offered an excellent opportunity to determine the efficiency of control measures alone when such measures were vigorously and intelligently administered in a relatively large naval group that could be rigidly controlled. The test was successful. The incidence of malaria during the first year of American occupancy of the air base was less than one-half of one percent and the cases that did occur included men newly arrived from other theaters in whom recurrences, rather than new infections, were possible. The incidence of the disease showed a slight but steady decline during the remaining years of American occupancy.

Malaria presented no problem in the other U. S. naval bases in French North Africa. This was due principally to the low incidence of the disease in the ports where the bases were located but it was implemented by anti-malaria regulations promulgated by the U. S. naval commander in the theater. These directed the screening of all living and sleeping spaces located in fixed structures. Drainage or oiling of all collections of water where mosquitoes could breed in and near U. S. naval establishments, the mandatory use of mosquito nets by all personnel, the use of mosquito repellents by personnel working in the open or in unscreened buildings after dark during the malaria season and the use of freon-pyrethrium and DDT sprays in offices and living spaces. It was directed that local commands terminate liberty at sundown in communities where malaria was reported. The use of atabrine for suppression was left to the discretion of local commands with directions to institute its use immediately if malaria occurred within the command and a rising incidence indicated failure of the mosquito control measures.

It did not prove necessary to resort to the use of atabrine in any U. S. Navy base or for any U. S. Navy personnel operating under their own commands. Army forces in camps and staging areas in all parts of the country, many of which were unsanitated, and those engaged in combat operations were compelled to rely upon suppressive treatment.

Malaria is endemic in French North Africa and will always be a factor to be considered in military operations. The insect vector is found in all parts of the country and the human reservoir of infection is constantly present in the Arab population, a race that is normally nomadic and whose movements are unpredictable and practically impossible to regulate. There is probably no part of the country where mosquito control measures will not be successful if sufficient time is allowed to place them in effect and if the required men, equipment, and materials are made available. The fact that the disease proved no serious handicap in this campaign indicates that present methods of malaria control are satisfactorily adequate in this particular region.

DYSENTERY

Bacillary dysentery is endemic in the entire Mediterranean area, including French North Africa. The French Public Health authorities reported that mild diarrheal disturbances occurred in the spring, summer and autumn seasons and that cases could be found in practically every community. Flies are unusually prevalent during these seasons and undoubtedly are an important contributing factor, as in the unsanitary manner in which the Arabs live. Every city, town and village became war conscious immediately following the invasion, and in anticipation of heavy air raids, constructed numerous slit trenches for their protection in their parks, gardens and fields. The ubiquitous Arab very quickly discovered that they made excellent latrines and by the spring of 1943 it was most unusual to find one that had not been repeatedly fouled with human feces, unless it had been kept under the strict and constant surveillance of guards.

Bacillary dysentery made its appearance early among the invasion forces in North Africa and continued to be a threat as long as they remained in the Mediterranean Theater. Fortunately, the disease occurred in a relatively mild form but this was due entirely to luck and could not be attributed to any control measures. The fact that it occurred in any form was indicative of inefficient control measures. The principal offending organism was Shigella sonnei but at various times and in numerous places 70 enteric pathogens were isolated from active cases. Numerous cases of acute gastroenteritis were studied in which Pseudomonas aeruginosa was found in overwhelming numbers and occasionally in pure culture.

The disease appeared in all the newly established bases during the spring of 1943. The outbreaks were explosive in character and affected most of the attached personnel within a few days. The cases varied in severity, the more severe ones suffered

severe and violent diarrhea with blood-tinged stools and moderately severe constitutional symptoms. All cases usually cleared up in about one week under a regime of restricted diet, sulphaguanadine, or sulphathiazole, and rest. The commands were seriously handicapped by the attendant loss of manpower and urgently needed work was delayed.

A definite pattern was found to exist in all of the outbreaks. The new bases were established in haste with directives to begin operations as quickly as possible. Too little attention had been given during the planning stages to the housekeeping arrangements to be placed in effect and structures near the water front were requisitioned for offices and living spaces without enough regard being given to their sanitation. Messing facilities were established immediately upon arrival by the commissary groups, in buildings of fairly large size, and usually without any consultation with the medical department in respect to their possible sanitary hazards. Toilet facilities in French North Africa are always minimal and the new bases augmented them by pit latrines. Fly proofing of latrines was frequently most haphazard and carelessly attended to and it was not appreciated that incomplete fly proofing is, for all practical purposes, no protection at all. Intentions were always good regarding the screening of galleys and mess halls but too frequently this was regarded as a refinement of civilization, rather than a public health necessity, and was assigned a place far down on the list of priority. The medical officers attached to the new bases were Reserve Corps officers with a negligible amount of previous naval or military experience. Their principal concern was to set up their dispensaries so that they would be in a position to care for sick and wounded men if the occasion should arise. Their preliminary briefing before arrival in the theater was practically nil. It consisted of being told by someone on the planning staff that on an unspecified date they would be landed with sufficient equipment to set up dispensaries of specified size and that they should investigate and determine if they had everything they needed in the equipment that had been allocated to them. Fortunately, there was a universal distrust of the water supply at the new bases and Lyster bags were used by all hands until the local supply was demonstrated to be safe after arrival.

Sanitary control over the preparation and handling of food, sewage and garbage disposal and water supply for drinking purposes was gradually established. Administrative officers were indoctrinated in the basic facts of dysentery control and medical officers and hospital corpsmen were reeducated in the same principals and in their responsibilities in the matter. All galleys and mess halls were tightly screened against the entrance of flies and were supplied with double swinging screen doors at all entrances and exits. Mess gear was washed in hot soapy water and rinsed in boiling water and, whenever practicable, it was stowed between meals in fly proof compartments. When this was not possible it was dipped in boiling water immediately before food was served. Existing toilet facilities were improved and enlarged as materials became available. Latrines were abandoned as quickly as possible, and when this was not possible, they were all rendered fly proof with frequent inspections to insure that they were kept so. Cases of the disease in personnel preparing and handling food were given special study to eliminate the possibility of carriers continuing to spread their infection after their recovery. Close liaison with the local health authorities was maintained in checking the potability of the local water supply and in learning of local centers of the disease in the community. An intelligent system of garbage disposal was placed in operation and fly breeding places in the immediate vicinity of bases were eliminated with the cooperation of the local civil authorities. Personnel were indoctrinated in preventive methods. They were impressed with the fact that dysentery is completely preventable and that the principal source of human infection requires a chain of three links—feces, flies, and food—and that successful control measures broke the line of continuity between them. The incidence of the disease very sharply declined when these regulations became routine. Sporadic cases continued to occur all through the period that American forces were in the theater but the infection in these later cases was acquired by carelessness in choosing places to eat and drink on liberty.

Bacillary dysentery will remain an endemic disease in French North Africa as long as the Arabs are there and as long as there continues to be flies to carry the infected material from diarrheal stools to food supplies. The control of the disease is a public health problem and will be a very difficult one for the civilian authorities because of

the filthy personal habits of the Arabs. The squalid and overcrowded conditions in which they live practically insures continuation of endemicity. However, there is no necessity for a military organization to pass through a cycle of learning control methods as they go along. Bacillary dysentery is absolutely preventable and prevention should be a responsibility of the planning staff before new bases are established. Prospective medical officers should enter into the planning phase to the extent that they will be made conversant with the problems they are likely to meet and they should be given the requisite authority to compel the cooperation necessary to insure complete protection from the very first day.

SAND FLY FEVER

Sand fly fever is another disease that is endemic in the coastal areas of practically all the Mediterranean countries. Phlebotomus papatassii is indigenous and was found to be particularly prone to occur in large numbers in areas that had been heavily bombed. The rubble of the ruins apparently provided a desirable breeding ground as did underground caves and caverns. The incidence of the disease was unusually heavy at Malta where both factors were present. Repeated bombings had destroyed many structures in the inhabited areas and all important military offices were located in caves and underground tunnels. The disease occurred so regularly in U. S. Navy personnel sent there on temporary duty that a bout with the disease was considered standard operating procedure.

The ordinary wire screening used for protection against flies and mosquitoes and bed nets offers no protection against the sand fly. These insects are small enough to pass through the mesh. Phlebotomus papatassii is a weak flier and rarely travels any appreciable distance from the place of its origin unless transported artificially or by wind currents. Control measures consist of eradicating breeding areas in and about the living and sleeping spaces. Rubble and refuse must be cleared away. Living spaces should be regularly and thoroughly sprayed with an insecticide; DDT proved to be most effective. Particular attention should be paid to the cracks and crevices in the floors and walls of buildings and to dark musty basements and subbasements. These simple precautions will do much to lessen the chances of infection from the insects carrying the virus.

Sand fly or phlebotomus fever is an acute virus infection closely resembling dengue. The onset is sudden with severe headache, marked malaise, a temperature elevation of 2 to 4 degrees that usually continues for about three days. When the fever subsides convalescence begins and there is no secondary rise such as occurs in dengue. Occasionally fever will continue for several days without marked remission. There is never any associated skin rash, the white blood count tends to be leucopenic with a relative lymphocytosis and all agglutination tests are negative. Complications are rarely experienced. Treatment is symptomatic, none of the new chemotherapeutic or ambiotic agents have any effect in aborting or shortening an attack. It is believed that an attack confers immunity for a short period of time but second and third attacks have been reported in the same individuals.

TYPHUS

Typhus always has been a threat in the countries and islands of the eastern Mediterranean. Repeated epidemics have occurred in the Balkans, in Asia Minor and in Egypt and the disease has been endemic in the countries and islands adjoining these areas. No difficulty was experienced with the disease by the Armed Forces operating in the Mediterranean Theater, however, until December 1943 at which time an epidemic of major proportions was threatened in Naples.

The disease was not reported as occurring in French North Africa during the period American forces occupied the country. The insect vector, however, is abundantly present in the Arab population and if the virus were introduced the disease could easily assume epidemic proportions. The ease with which military personnel may become infested was demonstrated many times during the occupation. Naval personnel frequently reported the presence of body lice on their persons after returning from liberty. Some admitted close association with Arab women but the majority denied closer association with Arabs than that which occurred in crowded streets or in curio shops. An investigation revealed that the public picture shows and the public conveyances were literally crawling with the insects and patronage of either invariably

resulted in infestation. This information was given wide publicity among naval personnel.

The exact origin of the Naples epidemic was never ascertained but it is believed that a few cases, six in number, occurred in March 1943 among some Serbian prisoners of the Italians in a prison camp near the city. There is also an unconfirmed report that cases occurred at about the same time in German troops encamped near the city. The build-up of the incidence to epidemic proportions is shown in the following table compiled from statistics made available by the Italians and from Allied records after the capture of the city.

MONTH	CASES	CUMULATIVE FREQUENCY	DEATHS	PERCENT MORTALITY
March 1943	1	1	0	0
April	3	4	1	33
May	6	10	2	33
June	0	10	0	0
July	2	12	1	50
August	12	24	2	17
September	19	43	4	21
October	27	70	10	37
November	50	120	13	26
December	341	461	66	19
January 1944	1014	1475	145	14
TOTALS	1475		244	

The opportunities for an epidemic were abundantly present, as mentioned previously. They may be presented here in more detail.

1. There was an original seeding of the population from infected persons arriving from the Balkans as prisoners of war.

2. There was an extensive rise in the louse population of the community due to a disruption of the water supply system, an absence of soap and a lack of desire for personal cleanliness. Added to this was the onset of colder weather and the corresponding use of more clothing. Then there was the overcrowding of the terrified population into the air raid shelters where many lived for weeks at a time amid surroundings of indescribable filth.

3. Food supplies were very short and actual famine existed among the poorer classes.

4. Medical care was practically non-existent and no attempt was made to isolate or quarantine early cases.

The epidemic remained confined to Naples for the first 10 months but at the end of that period it began spreading southward as the fighting moved northward out of Naples. The mortality rate was 16.5% which is surprisingly low in a non-immune population where a rate of 35% could have been expected. The case incidence was highest in the 10-24 age group and there was no apparent difference noted between males and females.

The initial phase of the control was started on 15 December 1943 by members of the Rockefeller Foundation Typhus Commission. The U.S.A. Typhus Commission assumed responsibility for the control measures on 3 January 1944. All suspected cases were investigated by Italian-speaking officers who sent confirmed cases to a contagious disease hospital. The patients were deloused and all clothing and coverings with which they had come in contact were steam sterilized. Suspected cases were reported by parish priests, the Health Department and members of the Typhus Commission. All contacts with actual cases were dusted with DDT. All habitations of overcrowding, particularly the ricoveros were dusted with DDT once a week as long as they were occupied. All hospitals, schools, prisons, orphanages and poorhouses were similarly dusted. Stations for a mass delousing of the entire population were set up in 42 locations in the city. The average station deloused 1,000 persons a day but as many as 5,000 were treated in a day during the height of the program. The maximum number deloused in one day in the city was 66,476, on 12 January 1944. A grand total of 1,633,134 were deloused between 15 December 1943 and 12 February 1944.

Refugees returning to Naples, Southern Italy or

Sicily presented a problem in the control of the spread of the disease. Incoming persons in this category were subjected to delousing before being permitted to enter and all out-going persons were required to present a certificate of a recent delousing before being permitted to leave. Vaccination played a very minor role in the control program among civilians and only approximately 45,000 injections of the vaccine were recorded during the program and these consisted of only the first of the series of three injections. Later mass injections of the civilians was instituted and 2 to 2½cc of the vaccine was given in one dose. During the height of the epidemic and the control program the Typhus Control force consisted of 36 American medical officers, 15 Italian physicians and 600 Italian civilians.

Only two cases occurred among U. S. military personnel, one in a vaccinated man from the 5th U. S. Army and one in an unvaccinated member of the U. S. Navy Guard Crew of the *S. S. John Banvard.* This low incidence was remarkable in the face of the serious epidemic where contact between the military personnel and the civilians was both close and constant. Credit for the low incidence was due in part to the vaccination program of the U. S. Armed Forces and to the higher standards of personal cleanliness practiced routinely by the Americans.

RELAPSING FEVER

Louse-borne relapsing fever occurred in an Italian prisoner of war in July 1943 in a prisoner of war camp in Tunisia. For the next few months a few sporadic cases were reported by the French among both European and Arab civilians but there was no indication of epidemic tendencies. Eight cases were reported in January 1944, 51 in February, 250 in March and from then on there was a monthly rise until the peak of 6,536 new cases were reported in March 1945 after which the incidence receded. A total of 41,755 were reported during 15 months in Tunisia and this was considered to be approximately one-fifth the actual number when the unknown cases among the Arabs was considered.

A U. S. Navy Epidemiological Unit was afforded the opportunity of studying the epidemic at close quarters and to assist the French health authorities in their efforts to control the disease. They closely observed the cases that occurred in two small Arab villages near a U. S. naval station. The mean age of the inhabitants of these villages was 24.7 years and the mean age of the patients was 22.6 years. The signs and symptoms of the disease were quite uniform in all patients, consisting of fever, headache, generalized malaise, chills, nose bleed, abdominal pain and occasionally vomiting. The majority of the patients showed a generalized petechial rash on the arms, chest and abdomen and an enlarged spleen. The rash appeared early in the disease as small, bright red petechial areas that faded to brown after 2 days and disappeared in about 5 days. Leucocyte counts were inconclusive. Twenty percent of the patients showed a slight neutrophilic leucocytosis, 20 percent had leucopenia with a relative lymphocytosis and 60 percent had normal white counts throughout the course of the disease. Blood in all cases was positive for spirochetes in stained smears as well as in dark field examinations. Agglutination tests with Proteus OX-19 antigen were negative in all cases, both during the course of the disease and after convalescence, thus ruling out a concurrent typhus fever infection.

No cases occurred among U. S. military personnel. The effectiveness of DDT against the insect vectors and the therapeutic value of penicillin was also studied. Fifty out of fifty-six persons examined during a preliminary louse survey were positive for body lice and nits. The entire population was dusted with 10% DDT in talc. Following this 9 new cases occurred within the next 9 days which was within the normal incubation period of the disease. No further cases occurred in these villages after that time. A second louse survey held at the end of the incubation period revealed no lice or nits. Twenty-seven patients with the disease were treated with penicillin. Adults were given 30,000 units intramuscularly every 3 hours for 48 hours. Children were given 20,000 units at the same intervals and for the same period of time. All positive blood smears became negative within 48 hours following which there was a rapid clinical recovery and no relapses.

PLAGUE

Bubonic plague has occurred sporadically in ports throughout the Mediterranean for many years but major outbreaks of the disease have been very

rare. Tunis reported 60 cases in 1934 followed by an average of 1 case a year until 1939 and 10 cases in 1940. A small outbreak occurred in Ferryville in the summer and autumn of 1944. The first case to be reported was in a 41-year-old civilian shipyard laborer of French-Italian extraction. His work was entirely in the region of the shops and never required his going aboard ships. It was his daily practice, however, to board every vessel that tied up at the wharf, or entered the drydock, to ask for food and other personal articles. He became ill on 3 August with severe headache, fever and chills which were thought by his civilian physician to be caused by malaria. He became progressively worse on oral quinine and died on 8 August, 4 hours after being admitted to the local hospital in a moribund condition. A deep left inguinal adenopathy was one of the presenting signs discovered at the hospital. Smears obtained from the spleen and inguinal lymph nodes at autopsy were positive for organisms morphologically resembling Pasteurella pestis and material from the bubo rubbed into the scarified skin of guinea pigs produced death of the animals in 5 days with typical findings of plague and recovery of Pasteurella pestis in pure culture.

The second case occurred in a four-year-old son of a French Navy Chief Petty Officer. The child had never been in the dock area nor in that part of the city where the first case resided. He became ill on 25 August with severe headaches, chills and fever and within a few hours developed an enlarged right axillary lymph node. He died on 26 August thirty hours after the onset of symptoms. Spleen and lymph node smears were again positive and the disease was reproduced in guinea pigs with recovery of P. pestis in pure culture.

The third case was in the ten-year-old son of a second French Navy Chief Petty Officer who lived about 200 feet from the home of the second case and who had been in close contact with that patient. He had received a 1cc injection of plague vaccine on 28 August and became ill on the following day with severe headache, fever and chills. On 1 September his temperature rose to 103° and pea-sized lymph nodes were found in the left inguinal region. He was taken to the local hospital where aspirated material from the enlarged lymph nodes was found to be positive for P. pestis and guinea pig studies confirmed the diagnosis of plague. He was placed on 1 gram of sulphadiazine by mouth every 3 hours for 3 doses and then 3 grams every 4 hours for 24 hours. His temperature returned to normal on the third day and the bubo decreased in size. On the fourth day the sulphadiazine was reduced to 1 gram every 4 hours and discontinued on the twelfth day. This patient recovered without any sequellae.

Sporadic cases of plague continued in Ferryville during the next 3 months. The exact incidence and the mortality rate were not reported to the Navy but unconfirmed reports were that about 30 cases occurred and that the mortality rate was 40%. Ferryville was the site of a U.S. Navy LCT Base and at the time of the outbreak of plague had a complement of 80 officers and men. They were promptly vaccinated with formalin killed vaccine containing 2,000 million organisms per cc in 2 injections at 5 day intervals, the first one-half cc and the second one cc. During the 4 months immediately preceding the appearance of the disease 190 rats were trapped by the Navy medical staff beneath the Quonset huts of the base, in the galley, under tent floors and along the sea wall. Twenty-four additional rats were trapped or poisoned after the outbreak of the disease. All were autopsied and none were found to be infected.

The Advanced Amphibious Training Base, Bizerte, was located about 10 miles from Ferryville. At the time of the plague outbreak in the latter place there were in excess of 10,000 U. S. Navy personnel stationed there. All were given plague vaccine in the same manner as those in Ferryville. A strict quarantine against entry into Ferryville, except on official business, was enforced on all U. S. military personnel. Rat extermination was intensified at the Bizerte base and 66 rats were caught. None was found to be infected. Traps and poisoned baits were used. The poisons used were barium carbonate, red squill and thallium sulphate on ground beef, bacon, salmon, rolled oats and whole wheat. Barium carbonate and red squill were found to be more effective than thallium sulphate.

A U. S. Navy team assisted the French health authorities in rat extermination in Ferryville. A total of 37 rats were taken by trap or by poisoned baits. They were of two types, the black house rat, Rattus rattus and the wharf rat, Rattus alexandrinus. The black rat predominated. Fleas found on live trapped rats were of three genera, the common rat flea, Xenopsylla cheopis, the human flea, Pulex irritans and the dog and cat fleas, Cteno-

cephalus canis and C. felis. The greatest number of fleas found on one rat was 100, predominantly X. cheopis. Three of the dead rats taken were positive for P. pestis.

An attempt was made to employ the insecticidal effect of DDT in the campaign against the disease by the U. S. Navy team assisting the French. A 5% solution of DDT in kerosene was thoroughly sprayed by motor-driven apparatus over all vegetation, refuse and areas frequented by rats in the hope that any fleas deposited in the regions would come in contact with the insecticide. Unfortunately this phase of the work could not be followed through because of the exigencies of the service but it is believed to be sufficiently promising to warrant its use in similar circumstances.

Human cases of plague occurred in Oran and Algiers at the same time Ferryville was having its cases. The exact details of these outbreaks were not fully reported but it is believed that about 80 cases occurred in Algiers and about 12 in Oran. It is known that 3 cases in Oran were of the pneumonic type. The usual precautions were taken in both cities by the military and civilian authorities. The disease did not appear among any U. S. military personnel.

An outbreak of human plague occurred in Dakar, Senegal, French West Africa in April 1944 and continued into the following November. A total of 567 cases were recorded with 514 deaths—a mortality rate of 91%. Dakar is a city of approximately 142,000 persons, 12,000 of whom are Europeans and the rest, 130,000, native blacks and Syrians. Overcrowding among this latter group was extreme in 1944 due to activities incidental to the war effort and the level of hygiene and sanitation among them was most primitive and their huts and houses and attached compounds were littered with food scraps, refuse heaps and trash piles which provided abundant food and shelter for a large rat population. Personal habits of cleanliness were at a low level and the flea infestation of individuals and their habitations was universal. Many of the houses and huts are sand floored and a standard piece of fly paper placed on the floors would usually collect 200 to 300 fleas within a period of 4 minutes. These body and house fleas were believed to have been the insect vectors among persons living in these overcrowded sections and to have been responsible for the spread and prolongation of the epidemic.

A total of 10,500 rats were taken during the course of the epidemic. 3,501 were examined for plague and 65 were found to be infected. The rats taken consisted of the Norwegian rat (Rattus norwegicus), the Alexandrine rat (Rattus alexandrinus), the common black rat (Rattus rattus) and the Camtchouli rat (Crycetomys gambianus). The first three were common, the fourth somewhat less so. With a few exceptions the infections were found to be limited to Norwegian and Alexandrian rats.

Statistical data is available on the cases treated in two hospitals, the Native Hospital and the French Military Hospital. The group so treated consists of 144 cases, 127 in the Native Hospital and 17 in the Military Hospital.

Type of Case	Bubonic	Pulmonic	Septicemic	Bubo-Septicemic
Number in Native Hospital	96	15	16	0
Number in Military Hospital	5	0	7	5
Mortality—Native Hospital	61%	100%	100%	—
Mortality—Military Hospital	0%	—	100%	20%

Both hospitals employed the same treatment and therapeutic agents but in a slightly different manner, as shown below:

Therapeutic Agent	Native Hospital	Military Hospital
Sulphapyridine	4-6 gms daily as long as fever continued.	8 gms daily for 3-4 days orally and intravenously then 3 gms daily as long as fever continued.
Sulphadiazine	Initial dose 2 gms then 1 gm every 4 hrs for duration of fever.	6 gms daily as long as fever persisted.
Plague Bacteriophage	1cc intravenously as long as fever persisted.	2-3cc 1st day then 1cc daily as long as fever persisted. Given intrabubo in bubonic type and subcutaneously in septicemic cases.
Plague anti-serum (Madagascar strain)	100cc daily during fever.	60-80cc daily intravenously during fever.

The results of the treatment at the Military Hospital are as shown below:—

	BUBONIC		SEPTICEMIC		BUBO-SEPTICEMIC	
	Cases	Deaths	Cases	Deaths	Cases	Deaths
Serum Sulphapyridine	1	0	4	4	1	0
Serum Sulphapyridine Bacteriophage	1	0	1	1	2	1
Sulphapyridine Bacteriophage	1	0	0	0	0	0
Serum Bacteriophage	0	0	1	1	1	0
Serum Sulphadiazine Bacteriophage	0	0	1	1	1	0
Sulphadiazine Bacteriophage	2	0	0	0	0	0
TOTAL	5	0	7	7	5	1

Sulphapyridine was considered ineffective and was discontinued when a sufficient supply of sulphadiazine became available. Statistical data is available only on the cases treated with bacteriophage and sulphadiazine and sulphadiazine alone in the Native Hospital cases.

It was the opinion of the medical officers treating the cases in both hospitals that bacteriophage was indispensable and that the best results were obtained from the combined use of bacteriophage and sulphadiazine. There was a 100% mortality among the septicemic and pneumonic cases, regardless of the type of therapy used. It was noted that the bubonic type of cases had very little chance of survival unless treatment was started before the fourth or fifth day of their infection.

A very extensive program of flea eradication was undertaken in an effort to destroy the insect vectors. The inhabitants of the flea infested area and their habitations were treated with DDT. The effort was 90% to 95% effective in killing all the insects.

YELLOW FEVER

Yellow fever is not an endemic disease in French North Africa, nor in any of the countries or islands of the western Mediterranean region. It is prevalent, however, in Equatorial Africa and personnel who entered or left the theater by way of tropical West African ports were subject to danger of infection. No cases were reported among U. S. military personnel and no measures, except routine vaccination, were necessary.

SULPHADIAZINE AND BACTERIOPHAGE

TYPE	CASES	DEATHS	MORTALITY
Bubonic	44	26	59%
Pulmonic	12	12	100%
Septicemic	8	8	100%
TOTAL	64	46	72%

SULPHADIAZINE

TYPE	CASES	DEATHS	MORTALITY
Bubonic	11	7	64%
Pulmonic	5	5	100%
Septicemic	3	3	100%
TOTAL	19	15	79%

SCHISTOSOMIASIS

It is generally believed that Schistosomiasis is prevalent throughout North Africa but this is not borne out by the records. One case of the disease

was reported among U. S. Naval personnel in the theater. It occurred in an enlisted man stationed in Algiers. The ova of the parasites were demonstrated in his urine several months after his arrival in the theater. The source of his infection could not be determined. A survey of all the fresh water streams in the vicinity of his ship failed to reveal any evidence of cercariae and the public health reports did not contain reports of any other cases. Surveys were conducted at the other Navy bases with similar negative results. It may be stated that the disease is present in the area but its incidence is slight and the danger from infection practically negligible. However, it is wise to caution personnel against wading and bathing in fresh water streams.

AMEBIC DYSENTERY

Amebic dysentery is endemic in the Mediterranean countries but does not constitute a serious health menace. Very little of the locally grown vegetable produce was used in feeding Allied military personnel because of the near famine conditions that existed among the civilians. The use of night soil for fertilization is not practiced as a rule and this in itself eliminates one potent source of the disease.

INFECTIOUS HEPATITIS

Infectious hepatitis proved to be the most troublesome disease condition throughout the entire theater. The local health authorities in all areas were in agreement that the diesase did not exist in the Mediterranean region before 1943, hence it cannot be attributed to any local condition. It was a by-product of the war. A few sporadic cases of what was diagnosed and treated as simple infectious jaundice occurred during the first months of the campaign but in no greater number than was experienced among the armed forces in the United States and Great Britain and they responded to the usual treatment and in a normal time. A more severe type of the disease appeared among the forces in Tunisia in June 1943 and gradually increased to epidemic proportions during the summer and autumn. When cooler weather began the incidence declined but did not disappear. It appeared among the forces in Italy and during the winter of 1944-45 became so widespread that the problem was considered serious.

In the earlier cases in Tunisia the onset was usually insidious with malaise, fever and a complete loss of appetite. In a few days nausea, vomiting, right upper quadrant discomfort, liver enlargement and usually a mild diarrhea appeared. The amount of fever bore no relationship to the severity of the disease. Some degree of jaundice was usually apparent after the fifth day, although some cases never became icteric, while others had an icterus index of 200. The degree of jaundice also had little or no relationship to the severity of the disease or to the prolongation of convalescence. Liver tenderness and liver enlargement were constant physical findings. Slight leucopenia was the rule although many white and differential counts never varied from the normal. Red counts and hemoglobin showed no alteration. The cases averaged 30 days on the sick list and eligibility for return to duty was based upon a return to a normal icterus index, disappearance of liver enlargement and tenderness and ability to tolerate physical exertion and a normal diet. About 10% of the cases had an acute stormy onset with fever, chills, nausea, vomiting and mild prostration. Relapses after apparent recovery became more frequent in the cases that occurred in the latter part of the Tunisian outbreak which appeared to indicate that the etiological agent was increasing in virulence as time went on. The mortality rate was 0.05%. The fatal cases were of relatively short duration and presented the signs and symptoms of liver function and the necropsy findings of yellow atrophy.

The fact that the disease made its appearance in the early summer and continued during the warm months, to decline in incidence with the advent of cooler weather, led to the belief that it was associated with the acute gastro-intestinal infections that were also prevalent during that period. All attempts, however, to identify and isolate the exact etiological agent were futile. Blood studies were negative for leptospira icterohaemorrhagia and other spirillae. All attempts to cultivate a virus from blood, urine and feces of patients with the disease were failures. The disease can be transmitted to man experimentally by feeding fecal washings and blood serum from patients in the pre-icteric and early icteric stages. The etiologic agent passes through a bacteria-tight filter and withstands a temperature of 560° for 30 minutes.

Early diagnosis is desirable in order that treat-

ment may be started before serious liver damage occurs. Ehrlich's urinary urobilinogen reaction and the cephalin-cholesterol-flocculation test are of great aid in making a diagnosis in the early phases of the disease before icterus appears and in those cases in which icterus never appears. There is no specific treatment. The best results are obtained with strict bed rest and a diet that is high in protein and carbohydrates and low in fats. The return to usual activities must be gradual and an extraordinarily long convalescence time must be accepted. Many of the cases that had recurrences were in men who were not kept in bed during the height of the disease or in those who engaged in physical exertion or returned to duty too soon. Dietary excesses and the use of alcohol must be avoided for a considerable period of time after apparent recovery. The return of anorexia, nausea, weakness and malaise have occurred months after apparent recovery, following over-indulgence in eating and drinking.

Control of the disease is maintained by observance of strict sanitation in bases and camps. The infectious material is introduced into the body by way of the gastro-intestinal tract, hence the protection of food and water supplies is all important. Occasional cases result from the introduction of the virus parenterally, in the injections of infected serum. There has been no evidence that the virus has been introduced by the bite or sting of an insect, although this is a physical possibility. Naval personnel were affected very little in comparison with Army personnel. In both, the incidence was highest in advanced areas where good camp sanitation was difficult or impossible to maintain because of combat conditions.

EXOTIC DISEASES

The exotic diseases, other than malaria, and the true tropical diseases are not indigenous to the Western Mediterranean lands. They are, however, common in Egypt and in Asia Minor. Malaria and the various dysenteric infections are endemic in all parts of Egypt, particularly in the upper provinces. Cairo and Alexandria have the facilities for satisfactory modern sanitation but they apparently are not efficiently managed and controlled. Numerous cases of gastro-intestinal infections occurred in Allied personnel stationed in those cities and in casual visitors on official missions. In many cases the infections were acquired in hotels and canteens where sanitary regulations which should have prevented all such infections were in force.

Schistosomiasis is a medical problem throughout the entire Nile valley, both for human beings and domestic animals. The slow moving water of the irrigation ditches in the cultivated fields contain the intermediate snail hosts. Human cases of the disease can be found in practically all Egyptian communities and it is impossible to raise cattle in many parts of Egypt because of the bovine infections. The cattle become infected upon eating grass and vegetation contaminated by the metacercariae and as high as 80% show the presence of Fasciola hepatica, the liver fluke.

Smallpox is constantly found in most Egyptian communities. There were 9,071 cases reported between 2 January 1944 and 27 May 1944 and of this number 562 cases were fatal. Trachoma and conjunctivitis are also common and cases of typhoid fever can always be demonstrated in the towns and cities of Egypt and Asia Minor.

The countries bordering on the Mediterranean are not particularly dangerous from the viewpoint of the naval and military medical authorities. Malaria presents the principal problem but the disease is amenable to mosquito control measures in most places, plus the use of suppressive treatment for forces operating in the rural areas where the native inhabitants provide a reservoir of infection and where the anophelene vectors abound. The gastro-intestinal infections are also a threat because of the constant source of infection in the inhabitants and the abundant opportunities for contamination of food and drink by the numerous flies. Strict sanitary control under military discipline, however, should be amply sufficient to protect the military forces. Egypt and the region around Suez are potentially more dangerous to military forces than any other areas in the Mediterranean because the populations living there are well seeded with many transmissible diseases, including malaria, typhus, schistosomiasis, smallpox and the gastro-intestinal infections.

CHAPTER 4

CARE OF BATTLE CASUALTIES

The care of the wounded must always be shaped by conditions and circumstances that govern the tactical situation at the moment. It is erroneous, however, to assume that the surgery of war is entirely molded by concessions to the need for haste and the confusion of caring for overwhelming numbers of patients. Military surgery is not to be regarded as a crude departure from accepted surgical standards, but rather as a development of the science of surgery to carry out a specialized and highly significant mission. Modern surgical treatment employs many adjuvants to operative techniques, such as chemotherapy, fluid replacement therapy, the transfusion of whole blood and fractions of blood employed as substitutes, potent anesthetic agents and narcotics. These tools are as important to the military surgeon as his scalpel, but are equally dangerous to the patient if used without expert precision. One of the major responsibilities of the military surgeon is to make full use of these and similar measures and at the same time to avoid the dangers that may attend their usage.

The ever present necessity for evacuation of the wounded to the rear is in fundamental conflict with ideal surgical management of the individual patient. To minimize this conflict, *close coordination between the functions of administration and professional services is required.* It is the responsibility of the medical officer charged with the surgical management of the patient to place technical procedures properly, both in time and in space, with due regard to the tactical situation on the one hand and to the welfare of the patient on the other. Unless the surgeon visualizes his position and the function of his hospital in relation to other surgeons and other hospitals, he may become confused in the mission he is to perform. Although some needed operation may be performed correctly, the military effort may be impeded and unforeseen harm done to the patient if the operation is done at the wrong time or in the wrong place.

It is the *responsibility of the force surgeon* charged with the establishment of evacuation and hospitalization policies to adapt the schedules of movement of patients to the maintenance of highest standards of surgical treatment. Priority of movement must be accorded to patients with certain types of injuries just as the duration of hospitalization in a given zone must be differentially adjusted to the urgent surgical needs of the patients. The term "nontransportable" as relating to the unfitness of battle casualties for interhospital transfer must, when military necessity permits, be extended beyond actual danger to life by a consideration of the likelihood of deformity, ultimate disability, and delay of recovery when these hazards exist.

PHASES OF SURGICAL MANAGEMENT

Just as the placement of various types of hospitals and consequently the provision of the facilities for surgery are determined by the geographic deployment of a military force, phases of surgical management exist that in general will conform with military echelons. These phases of surgical management are: medical aid measures, initial wound surgery, reparative wound surgery, reconstructive surgery, and rehabilitation measures.

Medical Aid Measures.—Within the divisional area, surgical management is limited to first aid measures and emergency resuscitation. Hemorrhage is controlled, splints and dressings applied, morphine administered for pain, plasma infused for

resuscitation, a booster dose of tetanus toxoid is given, and chemotherapy initiated.

Initial Surgery.—Actual conditions of warfare will determine both the facilities provided for emergency wound surgery and their location with reference to the combat area. In general, initial surgery is concerned with complete resuscitation so that surgery may be performed, and with surgical procedures designed to prevent or eradicate wound infection. Many of the seriously wounded casualties can be resuscitated only by a surgical operation in conjunction with transfusion and plasma therapy. For this reason, it is important that delays for the purpose of resuscitation ahead of an installation equipped for major surgery be kept at a minimum. Placement of the advance surgical hospital in physical proximity to the divisional clearing station accomplishes this end.

Reparative Surgery.—The general hospitals of the communications zone receive casualties from the hospitals of the forward area for further surgical management. As the initial wound operation is by definition a limited procedure, nearly every case requires further treatment. Soft part wounds, purposely left unsutured at the initial operation, are closed by suture, usually at the time of the first dressing on or after the fourth day. Fractures are accurately reduced and immobilized until bony union takes place. Designed to prevent or cut short wound infection either before it is established or at the time of its inception, this phase in the surgical care of the wounded is concerned with shortening the period of wound-healing and seeks as its objectives the early restoration of function and the return of a soldier to duty with a minimum number of days lost. In addition, it affords the return of patients to the zone of interior at an earlier date and in better condition, and minimizes the ultimate disability and deformity in the seriously wounded. The success of this important phase of surgery depends on the provision of an adequate period of hospitalization in addition to competent surgical care, particularly in specialized fields. It is not to be confused with the reconstructive phase of surgery, which may be postponed until return to the zone of interior. The ideal time for the procedures of reparative surgery will be found between the fourth and tenth days after wounding. The patient then becomes "nontransportable" for a period of time which, in the case of fractures, may extend to 10 or 12 weeks. Transfer of patients between fixed hospitals within the zone of communications must be regulated with these considerations in mind, otherwise the objectives of this phase of surgical management may be sacrificed. The establishment of special centers within general hospitals for certain types of surgery during this phase is highly desirable, as the procedures are oftentimes of considerable magnitude and call for mature and experienced professional judgment. Advancement of general hospitals in close support of Army or utilization of air evacuation from Army to more remote fixed installations are two measures that further the establishment of a program of reparative surgery. To use an oversea general hospital as a temporary custodial institution—a way station in a busy line of evacuation—where patients are held only if complications of the wound render them nontransportable, is to fail to utilize effectively and significantly one of the most highly integrated and specialized facilities of the medical service.

Reconstructive Surgery.—Early evacuation to the zone of interior is desirable for patients whose return to duty cannot be anticipated within the limits of the hospitalization policy of an oversea theater. The phases of reconstructive surgery and rehabilitation may then be integrated.

GENERAL PRINCIPLES OF INITIAL WOUND SURGERY

In the preoperative examination of a battle casualty, X-ray examination is essential.

Adequate assistance and instruments, a good light, and access to the wound that is unhampered by faulty position of the patient are basic requirements. Ample preparation of a wide field by shaving the skin will allow for extension of the incision or counterincision.

Bold incision is the first essential step in an operation on a wound. Adequate exposure is necessary to carry out *excision* of devitalized tissues. On the extremity the line of the incision is placed parallel with the long axis of the limb; elsewhere it follows the natural lines of skin structure. Only the devitalized skin of the margins of the wound is excised in a strip rarely wider than 2 to 3 mm. The creation of circular skin defects is avoided.

Incision and excision of the fascial layers is performed in the same manner to give free access to

devitalized muscle. Unrestricted exposure of successive anatomic layers permits the complete excision of devitalized muscle and the removal of foreign bodies.

The surgeon must be familiar with the blood supply of muscles, particularly large groups, like the gastrocnemius-soleus muscles of the calf, and respect these vessels in his dissection. Deep recesses of the wound containing foreign bodies may be approached by counterincisions planned anatomically rather than by sacrificing normal muscle structures.

Use fine hemostats. Use the finest ligature compatible with the procedure. Include the smallest possible amount of tissue in ligating a bleeding point. Do not repeatedly bite the wound with tissue forceps. Sponge gently with pressure instead of wiping. Remaining devitalized tissue produced by the missile or by the surgeon must slough before the wound can be closed by secondary suture.

Large wounds in regions of heavy muscles, particularly when complicated by comminuted fracture, require especial care. The depths of these wounds must be opened by a long incision with counterincision if necessary to allow free *dependent* drainage.

Only enough dry fine mesh gauze is used to separate the surfaces of the wound. It should be smoothly laid in the wound—not "packed."

Ether, white soap, and benzene have slight but definite necrotizing effects on living muscles. Green soap and various other substances used as detergents have greater necrotizing effects, whereas physiological saline solution is relatively innocuous. In general, progress in wound management points away from the introduction of any chemical agent into a wound for its supposed antiseptic effect.

Old wounds (48 hours or longer) are managed in accordance with the same principles, except that, in selected cases of established pyogenic infection and anaerobic cellulitis with toxicity, the general condition of the patient to withstand radical surgery may be improved by immobilization, penicillin, and repeated blood transfusions until an optimum time is selected for intervention. In postponement of surgery, the advantage that accrues from the immediate drainage of septic hematomas, large masses of dead muscle, and fascial plane abscesses is not to be forgotten. Postponement of surgery is not justified if clostridial myositis (gas gangrene) should be present.

Proper transportation-splinting is provided for skeletal and joint injuries. Soft part wounds are supported by firm pressure dressings and may, if extensive, be advantageously inclosed in a light plaster. Care is taken to avoid any constricting action of a pressure dressing placed on an extremity. Plaster casts must always be padded and split, or bivalved, before the patient is returned to the ward.

GENERAL PRINCIPLES OF REPARATIVE WOUND SURGERY

On arrival at a hospital where bed care can be assured for a period of at least 15 days (soft part wounds) the original dressing is removed in the operating room under aseptic precautions. X-ray films should be at hand. If the primary wound operation has been complete and has been properly done, all superficial wounds and many deep wounds may be closed by secondary suture at this time (4 to 10 days). Foreign bodies in soft parts adjacent to the wound are removed. Following suture, the part is immobilized, preferably by a light plaster, or if this is impractical, by bed rest.

The presence of residual dead tissue or established infection manifested by profuse discharge of pus, reddening and edema of the wound margins, persistent fever or toxicity is an indication for delay in secondary suture. When these manifestations are present but minimal, the wound is allowed to "clean up." This process can be hastened by moist dressings or by additional surgical excision of devitalized tissue remnants. Secondary suture can then be performed in a few days. If established infection is severe, or if the patient is toxic and anemic from deep-seated sepsis, a course of penicillin therapy and blood transfusions is instituted and followed by radical wound revision and staged closure.

Wounds that have been laid open properly at the initial operation tend to gape widely and give the impression of extensive skin loss. This appearance is actually due to loss of support of the deep fascia. Skin defects are more apparent than real in the majority of cases. Closure of a defect due solely to loss of skin is made from local tissue. Undermining

with advancement or rotation of flaps provides sufficient skin in nearly all instances and is preferable to grafting.

Technical considerations that are important to the success of secondary wound closure are:

1. Atraumatic handling of tissue.

2. Avoidance of tension sutures.

3. Accurate approximation of skin margins. The epithelial bridge is the main support of the wound for a considerable period of time.

4. Obliteration of dead spaces by pressure dressings and immobilization. Stab-wound drainage may be instituted when desired and is preferable to drainage through the suture line.

5. Leaving sutures in place for 12 days if stitch infection does not develop.

6. Suture in straight lines rather than the creation of sharp angles.

Preliminary bacteriologic analysis of the flora of a wound does not provide information pertinent to making the decision to perform secondary suture or allow the prediction of the result. If the suture is not successful because of infection, appropriate studies and corrective therapy are instituted before resuture is attempted.

The conditions that most often jeopardize results are:

1. Suture of a wound that is discharging pus. This usually means dead tissue in the depths.

2. Too early motion. (Wounds breaking down for this reason should be immediately resutured.)

3. Unrecognized foreign bodies adjacent to the wound.

CONSIDERATION OF CLOSED PLASTER TREATMENT

(Methods of Ollier, Pirogoff, Orr, and Trueta).

The regimen of closed plaster management of war wounds is not considered as satisfactory as the method described above, when field conditions permit the use of the latter. It is advisable to remove the initial dressing for inspection of the wound in all cases at least by the fifteenth day.

While the necessity for the rapid turnover of large numbers of casualties might justify an adoption of the closed plaster method of management of compound fractures, a high penalty in the form of skeletal deformity would be the inevitable result. Results obtained by secondary suture do not justify the use of closed plaster for soft part wounds.

When it is desired to allow granulations to cover exposed bone in deep irregular wounds, the wound may be encased in plaster subject to infrequent changes. This is also an accepted method of management for established infection of bone, particularly when the wound has caused an extensive loss of overlying soft parts or there is a large bone defect. Before application of the plaster, all devitalized tissue and loose bone fragments are excised. There should be no pocketing or pooling of pus in the fracture site or adjacent fascial compartments. Small surfaces of bare cortical bone may be removed surgically when this permits closure of the defect by suture or skin graft.

CRANIOCEREBRAL WOUNDS

Deep infection of penetrating wounds of the skull is almost always associated with incomplete removal of devitalized brain substance. The extent of the necessary débridement is oftentimes indicated by indriven bone fragments which are demonstrable by X-ray examination. Stereoscopic roentgenograms are helpful. A reduction in the incidence of infection can be effected by extending the débridement so that *these fragments of bone and the tissue that surrounds them are removed* at the time of the initial surgical procedure.

Dura defects are repaired by living grafts of fascia or pericranium. The scalp is closed by suture.

When a patient arrives at the base following initial débridement and closure of the wound in the forward area, neurological changes are carefully noted. When compared with former observations these may suggest improvement or regression. Signs or symptoms of increasing intracranial pressure usually indicate deep wound infection, hematoma, or a mass of residual necrotic tissue. The tension and healing in the scalp flap and wound are at once determined. Should stereoscopic X-ray studies disclose the presence of residual bone fragments, secondary wound débridement can then be more readily directed. Even in the absence of symp-

toms it is usually wiser to remove large or clustered bone fragments. On the other hand, if the fragments are small or in a dangerous location, operation may be withheld, provided the patient is doing well and can be held for a period of observation. If secondary operation is to be carried out, necrotic or infected tissue and hematoma are removed and wound closure effected, even though frankly purulent cerebritis has been encountered. At times a temporary drain to a large dead space is permissible, or repeated aspirations employed, but only rarely is it necessary to exteriorize the infected area.

EYE INJURIES

Conservation in the enucleation of eyes in forward installations is advisable. Inasmuch as sympathetic ophthalmia never develops before 10 days and usually not before 2 weeks after the initial injury, the first 2 weeks following the injury may be considered the "safe period." Therefore, in forward installations enucleations should be done only when there is extensive damage to the eye and orbit, and removal of the ocular remnants is a necessary procedure in the débridement of the area. Enucleation with a glass ball implant in Tenon's capsule is the operation of choice. Evisceration should be limited to those cases showing a purulent endophthalmitis.

Pending enucleation, or while awaiting the repair of an eye injury, the injured eye is atropinized, ophthalmic ointment applied, and both eyes bandaged. The immobilization of both eyes is particularly important, as movement of the eyes is minimized with lessening of the danger of wound gaping and further prolapse of the intraocular tissue.

Every case of perforating injury is X-rayed as soon as possible to determine the presence or absence of an intraocular foreign body. Patients suspected of having an intraocular foreign body are best transferred to an installation where a giant magnet and accurate methods of X-ray localization are available. The removal of an intraocular foreign body should be attempted as soon as possible unless an established iridocyclitis is present.

Tarsorrhaphy is indicated in certain cases for protection of the eyeball during evacuation. The lids should be sutured together whenever there is serious injury or burn of the eyelids, or an exposed eyeball. This is accomplished in most cases by "freshening" the nasal and temporal lid margins and sewing the lids together with fine silk. Where there is much destruction of one of the eyelids, the other can often be brought up to cover the eye. If both lids are destroyed, the eye should be covered by a skin flap as a temporary measure.

MAXILLOFACIAL WOUNDS

The hazards to life of initial operative management are oftentimes greater than those of the original wounding. There should be no hesitancy in performing tracheotomy when indications exist to relieve obstruction of the airway by that method. On the other hand, the care of a tracheotomy is difficult in a long evacuation line, frequently requiring a personal attendant. The choice of the anesthetic agent, as well as the technics of its administration, requires expert judgment and skill.

The procedures of initial surgery are based on the following principles in order of importance:

1. Reduction and fixation of fractures of the bony foundation structures. This may be by temporary measures for transportation purposes, with the intent that it will be replaced by more elaborate and precise splinting at a rear installation.

2. Isolation of the buccal cavity from the wounds of the bone and superficial soft parts by suture of the mucous membrane.

3. Primary closure of the muscles and skin with provision for adequate drainage in anticipation of infection. If the defect is such that primary closure is not possible and the wound enters the buccal cavity, the edges of the skin and mucous membrane should be carefully approximated.

4. Application of moist pressure dressings.

The management of the soft-part wound by primary suture, with or without plastic repair, must not tempt the forward surgeon to hold a patient for supervision of healing, with the result that precise and firm splinting of the bony parts is postponed.

Those cases with severely comminuted fractures or loss of bony substance, and with major soft-tissue defects, require evacuation to the zone of

interior as soon as they can care for themselves and after the dangers of infection have passed.

THORACIC WOUNDS

It is important to recognize two distinct phases that may be encountered in chest wounds: disturbance in cardio-respiratory physiology, and infection. The former develops immediately; the latter is usually delayed. Accordingly, in the forward area efforts are directed toward the restoration of physiologic equilibrium, whereas the less urgent complication of infection, if it occurs, may be controlled adequately at the base. Thus, success in the management of penetrating wounds of the chest depends upon the judicious timing and selection of surgical measures.

Occlusion of open chest wounds with gauze and adhesive strapping is the preferred management until the patient reaches a hospital staffed and equipped to carry out intrathoracic surgery.

Patients with a chest wound suffering from shock may be more advantageously treated in the prone position with the foot of the litter elevated than in a sitting position. Control of urgent physiologic disturbances that attend wounds of the chest in both preoperative and postoperative periods can be achieved by—

1. Needle aspiration of air and blood. Early and repeated aspiration of hemothorax without air replacement is essential in the proper management of chest wounds.

2. Bronchoscopic or catheter aspiration of blood and mucus from the tracheo-bronchial tree.

3. Infiltration of the intercostal nerves with procaine hydrochloride solution for relief of chest wall pain. This enables the patient to cough effectively and clear the air passages of blood and secretions.

4. Insertion of a catheter with a flutter or water-seal valve for pressure pneumothorax.

5. Administration of oxygen and whole blood transfusion. Autotransfusion of pleural blood should be used when practical. Care is taken to give the blood slowly in resuscitation after the systolic blood pressure has reached 80 mm of mercury, and the total amount administered should be only that essential to attain adequate resuscitation.

6. Débridement of sucking wounds, with hemostasis of intercostal vessels and approximation of deep structures of the chest wall to close the pleural opening.

An anesthetist well trained in endotracheal anesthesia for thoracic surgery is an essential member of an operating team caring for war wounds of the chest. Endotracheal oxygen-ether, administered through a closed apparatus capable of maintaining positive pressure, is the form of anesthesia recommended in the management of penetrating and perforating chest wounds.

Early thoracotomy through an extension of the wound or by a separate incision at a site of election, is indicated in the presence of—

1. Continuing intrapleural hemorrhage not controlled by hemostasis in the chest wall débridement.

2. Anatomic likelihood of diaphragmatic penetration.

3. A missile in the mediastinum or that has traversed the mediastinum with evidence of visceral damage.

4. Large intrapleural foreign bodies or debris that is readily accessible by extension of the wound.

5. Wounds of large bronchi or the intrathoracic portion of the trachea.

The following conditions are not in themselves indications for early thoracotomy either by extension of the wound or by separate incision:

1. Foreign bodies; that is, metallic fragments, rib fragments in the lung, or small fragments that may be in the pleural space.

2. Hemothorax. (Evacuation of blood from the pleural cavity by suction at the time of chest wall débridement is not considered a thoracotomy.)

3. Lacerated or contused lung, unless there is definite evidence of continuing hemorrhage.

The incision for thoracotomy, or an extension of the wound, should be placed in the postero-lateral area of the thoracic cage, rather than anteriorly. Difficulty has been encountered with the breakdown of anterior chest wall defects. Following thoracotomy, closed drainage of the pleural space is instituted unless definite contraindications exist. The drainage catheter is removed as soon as the

clinical course permits, usually at the end of 48 hours.

Rather than invite pulmonary edema by excessive intravenous fluid therapy, it is advisable to keep a patient with an injured lung slightly dehydrated.

Late complications include residual "clotted" hemothorax and empyema.

1. The accumulation of massive clots of fibrin in the pleural cavity is suspected when clinical findings persist and only small amounts of blood can be withdrawn with the needle. In addition, serial roentgenograms show no improvement during the third to sixth weeks. In such cases thoracotomy is done for the removal of clots from the pleural cavity and the dense layer of fibrin from the underlying lung. Early decortication in these cases permits normal expansion of the lung and prevents chronic empyema and other complications that lead to chronic disability. Penicillin is used both systemically and locally in the pleural cavity at the time of operation.

2. Empyema complicating hemothorax demands prompt surgical drainage or, when the patient's condition permits, radical thoracotomy with the evacuation of residual clots and decortication of the lung. The latter procedure should be performed preferably before the tenth week, because the surgical line of cleavage becomes obliterated after this time by organization of inflammatory exudate. Systemic and local penicillin is used as an adjuvant.

ABDOMINAL WOUNDS

Resuscitation.—Surgical management of penetrating wounds of the abdomen demands rapid resuscitation with adequate amounts of whole blood and plasma and early operation. Continuing internal hemorrhage or advancing peritonitis frequently prevents a satisfactory response to blood transfusion, forcing the surgeon to proceed with operation and rely on support of the patient by transfusion during and after surgery.

Preoperative Measures.—Nasogastric intubation, with removal of gastric contents, is an important measure to prevent the aspiration of this material during anesthesia. It is a fortuitous event when passage of the tube provokes vomiting. Testing of the nerve function of the extremities and rectal examination to determine the presence of fresh blood indicative of injury to the rectum are the two most commonly overlooked features of the preoperative examination.

Anesthesia.—Ether-oxygen anesthesia with a closed system, and preferably with an intratracheal tube, is the method of choice. Supplemental block of the field either by local infiltration or injection of the lower intercostal spaces in the axillary line may minimize the necessity for carrying these patients into the deeper levels of general anesthesia. Facilities should be available for bronchoscopy during or subsequent to the operation if there is reason to believe that gastric contents have been aspirated into the tracheo-bronchial tree. Postoperative aspiration pneumonia ranks with peritonitis as a life-endangering complication.

Incisions.—The vertical paramedian incision affords the most useful approach and is least liable to complications. Fecal contamination of the peritoneal cavity will be reflected by postoperative infection of the abdominal wall incision in a considerable number of instances. The principles that apply to the management of heavily contaminated soft part wounds also apply to abdominal wall incisions, provided steps are taken to prevent evisceration. The peritoneum is closed, usually including the posterior rectus sheath in the suture line. The rest of the abdominal wall is loosely approximated, preferably with stay sutures of braided silk or wire. The skin is left unsutured. The provision of adequate drainage for the abdominal wall incision, the avoidance of buried sutures and ligatures, and a loose rather than taut approximation of the stay sutures are the most effective measures in the prevention of infection. When it is necessary to exteriorize segments of bowel or to provide intraperitoneal drainage for or in anticipation of localized sepsis or a fecal fistula, secondary incisions are made. These are short, laterally placed incisions that follow the direction of the fibers of the external oblique muscle. In the upper abdomen, incision for exteriorization of bowel must not impinge on the costal arch.

Small Bowel Injuries.—Depending upon the extent of damage, repair is done by suture or by resection and anastomosis. Exteriorization of small intestine or double-barreled enterostomy is avoided as productive of serious life-endangering complications.

Large Bowel Injuries.—It is important to note the distinction between exteriorization of a wounded segment of bowel and construction of a colostomy to divert the fecal stream. At times both purposes may be accomplished by one and the same procedure, but a clear understanding of the purpose of the operation is essential to the selection of technics involved. For either purpose the basic technical requirement is adequate mobilization of the segment of the large bowel that is brought to the surface of the abdominal wall. Insufficient mobilization with dependence upon suture or clamps to maintain the bowel in its abnormal position will result in retraction. Retraction leads to a fecal fistula that may be difficult to repair or, in the case of a defunctioning colostomy, defeats the purpose of the operation by allowing fecal matter to enter the distal segment. Early in the convalescence, retraction is productive of abdominal wall infection or intraperitoneal sepsis.

1. *Exteriorization.*—Exteriorization of the damaged segment through a laterally placed muscle splitting incision is the established procedure in the management of wounds of the large intestine. The loop of bowel must lie comfortably on the abdominal wall without tension and with proper orientation of its proximal and distal limbs; that is, not twisted upon itself. The mesentery falls naturally into a fold on the medial aspect of the loop, leaving the bowel walls in contact on the lateral side. Properly performed, this simple procedure is adequate in the majority of instances when exteriorization is all that is required. Closure is made by suture or the application of a spur clamp in the area when the two limbs of the bowl are in contact. When the injury is larger than one-half the diameter of the bowel or a segment has been resected because of damage to the mesentery, exteriorization takes the form of a double-barreled spur. Sutures may be placed to approximate the antemesenteric borders of the intraperitoneal portions of the limbs for subsequent crushing by a clamp. Care must be taken not to penetrate the lumen of the gut or strangulate vessels by sutures.

2. *Sigmoid Colostomy.*—Colostomy to divert the fecal stream is required for: injuries of the pelvic colon below the level where exteriorization is possible (in such an instance the perforation is repaired by suture and proximal colostomy done); wounds of the rectum; and certain perineal and buttock wounds as an adjuvant to wound healing and secondary suture. An appraisal of the length of time that may be necessary to defunction the distal bowel segment guides the technical details of construction of the colostomy, as well as determines the site chosen for the artificial anus. A tube cecostomy or partial exteriorization of the cecum does not divert the fecal stream from the remainder of the colon, and is never used for this purpose. Colostomy in the left half of the transverse colon is a useful procedure in the face of extensive pelvic injuries that may require subsequent repair by the abdominal route. This is particularly the case if a suprapubic cystostomy is also indicated, or if the missile has produced damage to the abdominal wall in the left lower quadrant. Usually, however, a left sigmoid colostomy will be satisfactory for injury of the pelvic colon or rectum and for perineal injuries. Placement of the colostomy in a defect produced by the missile, or in the laparotomy incision, is to be avoided. Formation of a loop with proper lateral orientation of the bowel, assured if desired by the placement of a few absorbable sutures on the antemesenteric borders or approximation of appendices epiploicae, provides an adequate sigmoid colostomy. Formal construction of a long spur is not necessary and may be undesirable. Extensive damage to the lower bowel segment, associated injury of the bladder and urethra, and wounds that extensively compound the bony pelvis, as well as the rectum, are examples of injuries that require a prolonged and complete defunctioning artificial anus. Under these circumstances the exteriorized loop is made sufficiently long to allow for complete transverse section of the bowel and some separation of the two stomata. As ultimate closure will be by end-to-end suture, formation of a spur is undesirable. Construction of a skin bridge between the arms of the loop would, in fact, be preferable. Small perforations of the rectum, or instances in which the perforation cannot be demonstrated but is thought likely, may not require prolonged or even complete diversion of feces. Small wounds of the rectosigmoid may heal promptly if suture is technically satisfactory. Under such circumstances, formation of a loop colostomy with a tentative partial opening on the antemesenteric border will suffice until a complete appraisal can be made at a fixed hospital. Many of these cases can be restored to duty within an overseas theater by extraperitoneal repair of the incompletely divided loop. If the need for long and complete diversion of feces is demonstrated, the loop is

completely transacted to form an artificial anus. Colostomy as an aid to the healing of wounds of the buttocks and perineum need not be performed in the forward area unless laparotomy is being performed for other purposes. If done solely for management of the external wound, the patient will be rendered nontransportable because of a procedure that could have been postponed until arrival at a fixed hospital.

3. *Cecostomy.*—Tangential perforations of the cecum may be managed by a tube cecostomy or, preferably, by exteriorization. Single perforations require mobilization of the bowel to look for retroperitoneal perforation. Cecostomy, even when necessary because of direct injury to the cecum, is never to be used as a substitute for a proximal colostomy when indications for the latter are present.

4. *Right Colostomy.*—In extensive injuries necessitating resection of the cecum and ascending colon, the most important principle to observe is complete separation of the ileostomy from the laparotomy incision or from a large abdominal wall defect. The most satisfactory method for dealing with the end ileostomy is separation of the ileum and the proximal end of the colon by creating a terminal ileostomy in a separate incision in the right lower quadrant and exteriorization of the end of the colon below the coastal margin. Every effort should be directed to the early anastomosis of the ileum to the transverse colon.

5. *Perforations of Rectum.*—Wounds of the rectum are characterized by inaccessibility, difficulty of diagnosis, frequent damage to other structures and the hazard of pelvic and ascending retroperitoneal cellulitis. Deviations from the principles established for the management of wounds of the rectum continually lead to serious complications. Colostomy (not cecostomy) is mandatory, as also is free posterior drainage, best established by incision of the fascia propia exposing the rectal, sacral, and lateral paramedian spaces. Attempts to drain the retroperitoneal space by utilizing the missile wound of the buttock have been disastrous. In establishing posterior drainage it may be desirable to increase the exposure by removal of the coccyx. This is done as a disarticulation of the coccyx from the sacrum by sharp dissection and erasure of exposed articulating cartilage—not by incomplete amputation with a bone forceps.

Postoperative Care.—The postoperative care of patients with abdominal wounds is of the utmost importance and is the personal responsibility of the operating surgeon. Among the most important considerations are:

1. Holding of the patient until his equilibrium is established, oftentimes a minimum of ten days.

2. Nasogastric suction for 48 hours or more following operations.

3. Whole blood and plasma.

4. Parenteral fluid therapy is controlled by measurement of fluid intake and output and by determinations of cell volume and plasma protein concentration by the copper sulphate method. A daily urinary volume of 1,200 to 1,500 cc is maintained, a point of particular importance in connection with the use of sulfadiazine.

5. Aspiration of tracheo-bronchial secretions. Postoperative pulmonary complications including pneumonia, atelectasis, and pulmonary edema are common in this group of patients. Oxygen therapy by means of an indwelling nasal catheter and aspiration of tracheo-bronchial secretions by catheter or bronchoscope are important measures and may be required frequently.

Postoperative Complications.—In cases that develop sepsis, small intestinal fistula, intestinal obstruction, and other complications or sequelae, it is essential to—

1. Maintain nutrition by supplemental feedings.

2. Correct the tendency toward vitamin depletion.

3. Promptly diagnose and drain localized sepsis.

4. Close small intestinal fistulas at the earliest moment that operative intervention can be tolerated.

Closure of Colostomy.—A defunctioning colostomy deteriorates into a useless fecal fistula when it no longer diverts the feces from the distal bowl. Reappraisal of the purpose of its continuation must be made and it should either be closed or reestablished as an effective artificial anus. Spillage of feces into the lower segment results in fecal impaction and delays healing of the wound of the bowel wall. In oversea theaters it is desirable to close certain colostomies and repair exteriorized

segments, when this can be done, by suture of a partial defect of the bowel or by crushing a spur. Formal end-to-end suture is not recommended for oversea theaters unless the patient can be returned to duty in the theater.

PERIPHERAL VASCULAR INJURIES

Peripheral vascular injuries are of special importance, particularly where major vessels are involved. In many of these cases ligation or end suture will be necessary. Ligation in continuity should not be done. In the presence of thrombosis, the thrombosed segment is excised. Localized segmental spasm of the artery should be distinguished from thrombosis. Such cases, also termed "concussion" or "stupeur" of the artery, may follow various forms of trauma to an extremity, especially when the traumatizing agent passes near a vessel. In such cases the limb is cold, pale, and pulseless, but evidence of hemorrhage or hematoma indicating that the vessel has been lacerated is lacking. These cases respond well to débridement of surrounding traumatized tissue and to periarterial sympathectomy or sympathetic block. Postoperatively, in all cases with peripheral vascular injuries, vasodilatation may be induced by daily sympathetic block using 1 percent procaine hydrochloride solution. Body warmth is carefully maintained but heat should not be applied to the involved extremity.

The *position of the extremity* is important, as elevation may accentuate ischemia. A dependent position is preferable even if a moderate degree of edema appears to be the result. A plaster cast on an extremity threatened by ischemic gangrene is bivalved and the anterior half removed. Continuous observation is essential to detect impending anaerobic infection. Repeated transfusions to establish a normal blood volume and maintain a high red cell volume is an important phase of management.

A patient with *impending ischemic gangrene* should be held at the initial surgical installation until a favorable result is assured or amputation is performed.

Operation for the extirpation of an *aneurysm* or an *arteriovenous fistula* is rarely an emergency procedure. Since wounds causing aneurysms may be infected, and since extravasation of blood into the tissues, surrounding the wound usually occurs, delay in operation will diminish the chance of secondary infection and secondary hemorrhage. Moreover, *operation should be postponed until such time as collateral circulation has been established, so that major vessels may be safely ligated and divided.* This will usually require 3 or 4 months. Early operations are undertaken not for the cure of aneurysm but to arrest certain complications; namely, hemorrhage, impending rupture, nerve paralysis caused by pressure, or threatened gangrene of the extremity. In such cases, repeated sympathetic block using 1 percent procaine hydrochloride solution (or sympathectomy, if indicated) should be done both preoperatively and postoperatively to assure maximum vasodilatation and thus increase circulation in the involved part. Oversea patients with aneurysms should be evacuated to the zone of interior where, upon arrival, they should be sent to vascular surgery centers.

PERIPHERAL NERVE INJURIES

Complete palsy with anatomic division of nerve.

Primary suture of peripheral nerve injuries is advisable only during a period when small numbers of casualties are being handled or expected. In selected cases of soft part wounds uncomplicated by extensive muscle damage or skeletal fracture, complete or partial severance of a nerve may be repaired by formal suture following a meticulous initial débridement. Closure of the soft parts over the suture line without tension is advisable with primary or staged closure of the skin. This procedure should be undertaken only if the patient may be held under observation of the operating surgeon for a period of ten days, and is not recommended if the wound is heavily contaminated by debris or if evacuation from the field has been delayed. Primary nerve repair must never be undertaken at the expense of delay in débridement or neglect of concomitant injuries.

The *more usual method of management* will be by undertaking formal nerve suture as a phase of reparative surgery in the following stages:

It is the responsibility of the surgeon at the time of the initial débridement to make a careful record of the injury as he observes it. Preoperative appraisal of nerve injury is notoriously difficult and inexact in patients with multiple wounds, particularly if they are suffering from shock. The most

precise information comes from anatomic observations at operation. Here again, it is not desirable to embark upon a painstaking dissection with extension of the field of operation beyond the zone of devitalized tissues.

No attempt is made to repair the nerve by suture or to fix the nerve ends. Exposed nerves are covered with muscle so that the dry fine mesh gauze used in the wound is not in contact with the nerve. Petrolatum gauze is not recommended.

Dusting of the wound with sulfonamide after débridement should not be done in the area of the nerve trunk.

The joints above and below the point of injury are immobilized to minimize retraction of the nerve.

A firm pressure dressing supported by a light plaster of paris cast is applied to reduce wound exudation.

Penicillin therapy is maintained by the systemic route.

On reaching a general hospital the original dressing is removed under aseptic precautions in the operating room. This usually is possible on or shortly after the fourth day after injury. Appraisal at this time is based upon the ultimate functional restoration of the extremity, taking into consideration muscle damage and bone or joint lesions in relation to the nerve injury. Electrical tests may be made if desired. Oftentimes a more deliberate examination will correct or supplement the initial notes made in the forward area. Procedures such as muscle suture or even shortening of the limb by removal of the devitalized comminuted bone fragments may be carried out at this time. The divided ends of the nerve may be approximated by a single fixation suture or otherwise identified with metallic sutures. The wound is closed if sepsis is not present, or if, after further excision of sequestrating tissue, the wound appears adequately prepared for closure. Closure of the skin may be further staged, or, if a large skin defect exists, a skin graft is applied at once, or as a staged procedure.

When first intention healing has been secured—and this results in 80 to 95 percent of cases—formal suture of the nerve is performed under the protection of systemic penicillin. This should be feasible in many cases during the third or fourth week after injury.

Patients with major nerve injuries, whether suture has been performed or not, should be transferred to the neurosurgical centers in the zone of interior with the least possible delay. It is important that splints or casts be removed at the earliest possible date. Cases are being received in the zone of interior with muscle atrophy and joint fixation resulting from unduly long periods of immobilization by casts.

Partial or transient palsies make up perhaps one-fourth to one-third of the nerve lesions arriving at the base. Recovery from simple contusion often begins within a few days, while more extensive injuries may proceed over a much longer period of time. In these cases it is desirable, though not imperative, to visualize the injury to the nerve trunk at the time of primary débridement or secondary wound suture.

AMPUTATIONS

The most important phase in the management of amputations is the functional rehabilitation of the patient by the fitting of a prosthesis. Amputation centers have been established in the zone of interior for this purpose. It is the expressed desire of the Surgeon General that the early management of amputations in overseas theaters conform with policies that have been set forth in numerous bulletins and circular letters.

In the forward area, amputations will be performed at the lowest possible level except that a proximal amputation may be done in preference to a disarticulation. The technic for the performance of amputations is as follows: An incision is made through the skin at the lowest level compatible with viable tissue, and the skin allowed to retract; the fascia is then incised at the level to which the skin has retracted. The superficial layer of muscle is then cut at the end of the fascia and permitted to retract. At its point of retraction, the deep layers of muscle are cut through to the bone. After the deep muscles have retracted, the periosteum of the bone is cleanly incised and the bone sawed through flush with the muscles. No cuff of periosteum is removed as in a closed amputation. Bone denuded of periosteum will sequestrate if infection is pres-

ent, and a ring sequestrum often results when the periosteum has been removed. It is important also that no periosteum be elevated or torn from the bone in the stump by rough handling. The stump following a properly performed open amputation exhibits a slightly concave open cross section of the extremity and the skin can be pulled down gradually by traction to cover the end of the stump.

The proper dressing of the stump is important. The end of the stump is dressed with fine mesh gauze in such a manner that it does not overlap the skin edges. Skin traction is applied immediately by a stockinette cuff attached with ace adherent or by adhesive tape. Traction is obtained preferably by a light plaster cast incorporating a wire ladder banjo splint. The cast always incorporates the joint above the amputation; for example, a spica for an amputated thigh. Before evacuation, the traction is examined and if doubt exists as to its effectiveness, it is reapplied. The tension of the elastic cord should be maintained by adjustment during transit.

At the base areas, skin traction is continued until the stump is healed or the case is evacuated. Closure of stumps by sliding flaps, plastic resection with sacrifice of bone length, or formal reamputation are procedures to be carried out in the amputation centers in the zone of interior rather than in an oversea theater. Skin grafting in lieu of traction is not indicated. Vertical incisions in the stump made for control of infection or as part of the initial débridement should be closed by secondary suture while skin traction is being maintained to cover the defect at the end.

In the communications zone continuous skin traction is maintained in all cases. After removal of the cast or splint, maintenance of traction using 4 to 6 pounds in below-knee and 6 to 8 pounds in thigh stumps over a pulley at the foot of the bed is indicated. Traction is continued until maximum healing of the wound is obtained. Traction in similar fashion is indicated in upper extremity amputations. Priority air evacuation to the zone of interior should be available for amputation cases as soon as they are able to be transported. Traction during evacuation is the same as in *b* above. Patients with injuries requiring amputation will benefit by an explanation of why the amputation is necessary prior to the operative procedure. They should be informed further that additional surgical treatment of the extremity will be required before fitting the prosthesis.

COMPOUND FRACTURES

The management of a compound fracture is divided into the following phases: first aid splinting in the field; débridement and the application of transportation splinting in a mobile hospital; final corerction of the deformity and attainment of wound healing and bony union at a fixed hospital (reparative phase); reconstructive or corrective surgery (bone grafting, osteotomy, sequestrectomy, etc.) in the zone of interior. In every phase attention is directed to the *ultimate function of the extremity* which is dependent on muscles, nerves, blood vessels, and joints, as well as on skeletal integrity.

Transportation splinting applied subsequent to initial wound surgery for evacuation from mobile to fixed hospitals is not designed to provide anatomic reduction or prolonged fixation in suitable reduction. Except in rare instances it is by plaster of paris. Plaster bandages are adequately padded and bivalved or split through all layers to the skin. Skeletal fixation by the incorporation of pins or wires into the plaster is not recommended. The only indication for the use of internal fixation in the forward area is to preserve the vascular integrity of the extremity. Methods of transportation splinting that have proved safe and comfortable are:

Femur.—A low-waisted "one and one-half" double plaster spica with the knee slightly flexed and minimal abduction. The Tobruk plaster and the Navy leg splint with skin traction provide temporary immobilization for transportation over short distances. While not as effective or comfortable as a spica, they may be used as emergency measures or when large numbers of casualties demand concessions to operating time, or for special indications such as the presence of a colostomy or suprapubic cystostomy. When restricted to lower third femoral fractures or knee joint injuries, the Tobruk splint provides adequate immobilization.

Humerus.—Comfortable and effective splinting is provided by a thoraco-brachial plaster with the arm forward in internal rotation or a plaster Velpeau bandage binding the arm to the trunk.

The Navy humerus splint designed for field (first aid) use is not designed for postoperative transportation splinting. A hanging cast is both uncomfortable and ineffective as a method of transportation splinting.

Forearm.—A split or bivalved circular plaster cast that extends to the midbrachial region with flexion of the elbow or a plaster slab in the form of "sugar tongs" is recommended. The forearm should be held in midpronation.

Tibia and Fibula.—A split or bivalved circular plaster cast should be applied from toes to groin. The knee is slightly flexed (15°), and the foot held in neutral position at 90° to the axis of the lower leg.

Reparative Surgery of Compound Fractures.—Reparative surgery in compound fractures is made necessary by leaving unsutured the large incisions made for débridement and the recognized fact that splinting suitable for transportation is inadequate for complete reduction and fixation of the fracture. The goal is functional restoration of the extremity and demands treatment of muscle and nerve injury as well as skeletal damage. Observance of certain basic principles are important to the success of this phase of management.

Preoperative Correction of Anemia by Whole Blood Transfusion.—Despite whole blood transfusion for resuscitation in the forward area, a high percentage of compound fracture cases will arrive at a fixed hospital in the communications zone with low red cell volume (hematocrit) and hemoglobin. An approximate estimate of the quantity of whole blood needed to restore red cell volume may be deducted from the rough rule of 500 cc blood for each 3 points of the hematocrit or 0.9 gram of hemoglobin. In the use of whole blood transfusion for correction of secondary anemia or hypoproteinemia the total volume administered in a 24-hour period should not exceed 1,000 cc, except to replace blood lost at operative procedures. This is in contrast with the larger volumes that are administered for resuscitation when the total circulating blood volume may be greatly reduced. No correlation exists between the hematocrit or hemoglobin levels and circulating blood volume, and care must be taken not to precipitate pulmonary edema by overtransfusion of a patient in whom the blood volume has been restored by dilution but who still shows a greatly reduced cell volume (hematocrit) and hemoglobin.

Surgical Elimination of Residual Necrotic Tissue.—No available chemotherapeutic agent can "sterilize" an open wound containing devitalized tissue or blood clot. A properly managed clean wound requires no local antiseptic.

Control of Invasive Infection by Systemic Chemotherapy.—Systemic penicillin therapy in a dosage of 25,000 units every 3 hours is recommended as a routine adjuvant for secondary operations on compound fractures. Treatment is continued postoperatively until the likelihood of invasive infection is passed.

Reduction or Closure of Soft Tissue Defects.—Exposed cortex of bone, nerves, and tendons are vulnerable to the necrotizing effect of wound suppuration and are protected by the apposition of adjacent soft parts. Transversely divided important muscle groups are united by suture. Fascial compartments are restored, to minimize scarring and improve muscle function. Certain of these procedures may be staged operations. Emphasis should not be placed on early or complete skin closure, as in most cases any remaining cutaneous defect will heal before bony union occurs.

Provision of Drainage for Residual Exudate.—Severely comminuted fractures may require dependent drainage in association with the apposition of soft parts over exposed bone. Fascial plane incisions and separation of muscle bundles with fine mesh gauze to exteriorize the fracture site have proven superior to stab wounds or rubber drains. Upper extremity fractures rarely present a drainage problem. The thigh may be drained by a postero-lateral incision between the vastus lateralis and the biceps. An adequate posterior drainage route for the shaft of the tibia does not exist and such an injury may necessitate a period of nursing in the prone position ("on the face").

Internal fixation of battle fractures is not feasible commonly because of extensive comminution. Further, the method demands periosteal stripping and surgical trauma to the wound. Limitation of the use of this method to cases carefully selected by specialists fully experienced in the technics and hazards of its usage is strongly advised. An example of sound usage is the employment of screws for

restoration of the articular surface of a major joint. Reduction of the fracture—not the use of internal fixation—is part of the goal of reparative surgery.

Use of Suspension Traction.—The application of suspension traction in the treatment of fractures, particularly those of the femur, is the safest and most satisfactory method of management. In fixed hospitals, fractures of the femur should be treated by skeletal traction for 10 to 12 weeks, until enough union has been obtained to permit safe transportation to the zone of interior in a plaster spica. The use of suspension traction promotes the maintenance of joint and muscle function and prevents angulation or overriding deformity. Overpull and resulting distraction must be avoided at all times, particularly in cases associated with injury or division of the thigh muscles. Certain cases of this type require very expert attention and delay in the application of traction until firm fibrous union of muscles has been attained by suture.

JOINT INJURIES

Early complete débridement is the keystone of success in the management of wounds that compound a joint. The wound of the soft part is excised and the bone and cartilage damage assessed through incisions that provide complete exposure. Comminuted fragments of bone and cartilage are removed from the joint and a careful search made for foreign material. When it is necessary for badly comminuted fractures of the patella to be excised completely as a step in the débridement of a knee joint wound, every effort should be made after cleansing the joint cavity to close the capsule and to approximate the fibers of the quadriceps and patella tendons. The skin is left unsutured. Penicillin is inserted into a joint at the end of the operation. In joints that are accessible to needle aspiration, accumulating exudate may be withdrawn and penicillin injected during the postoperative period.

Closure of the joint is especially difficult in the face of extensive loss of soft parts. When it is impossible to close a joint by suture of synovia or capsule, an occlusive dressing is applied. On arrival at a fixed hospital, effort is directed toward closing the defect by advancement of a skin flap or other plastic procedure.

Adequate exposure of the *hip joint* is a specialized procedure that requires precise anatomical orientation. The same principles of management must be applied to improve the results after injury to this particular joint.

Wounds of the *ankle joint* with comminution of the os calcis or astragalus are peculiarly liable to sepsis. Initial débridement of comminuted bone fragments must be minimal if function is to be preserved. Efforts are made early in the reparative surgical phase to reduce or close the skin defect with split thickness graft when necessary. When sepsis is established, subperiosteal excision of necrotic bone fragments, followed by early wound closure by graft or suture, should not be delayed.

URINARY BLADDER INJURIES

Perforating wounds of the urinary bladder require repair. Drainage of the urine should be accomplished by suprapubic cystostomy, not by perineal urethrostomy. The space of Retzius should be drained always.

Certain technical details in the performance of suprapubic cystostomy are essential to successful subsequent management of the cystostomy. A number 34F Malecot or number 20F Pezzer type of tube *should be placed as high in the fundus of the bladder as possible* and brought out through the upper end of the wound. This placement is to avoid pressure necrosis and infection of the pubic bone and periosteum as well as trauma of the trigone by the proximal end of the tube. The suprapubic tube may be held in place by adhesive after the sutures have been removed.

BURNS

Progress in the treatment of burns is reflected in the more liberal use of whole blood transfusions during convalescence and the excision of third degree eschars to facilitate earlier skin grafting.

Medical aid or emergency treatment of the burned area is accomplished by the application of a sterile pressure dressing. The burned area is covered with strips of sterile dry fine mesh or petrolatum gauze and a thick layer of sterile gauze. This is held in place by firm bandaging.

Initial surgical treatment is instituted as soon as possible.

Resuscitation or prevention of circulatory failure is achieved by the adequate use of plasma. In extensive burns, quantities of plasma up to 12 units may be required in the first 24 hours.

Pain is relieved by morphine in dosage of gr. ¼. Pain should be differentiated from the restlessness and apprehension of anoxia. Barbiturates may be an effective supplement to morphine.

The dressing is changed in an operating room with full aseptic precautions. If the burned area appears clean, no further preparation of the wound is indicated. Small blisters should be left alone, but larger ones may be drained by simple puncture. Gentle washing and débridement are reserved for grossly soiled burns. General anesthesia should be avoided if possible. The burned area is covered with dry fine mesh or petrolatum gauze and a pressure dressing. On burns of the extremities the pressure dressing should include the entire extremity distal to the burn. Immobilization of the part by splinting is desirable when feasible.

Systemic penicillin therapy is instituted in preference to sulfonamide therapy.

The prevention of anemia demands liberal use of whole blood transfusions as soon as the initial hemoconcentration is corrected. Protein depletion is offset more effectively by increased dietary intake and whole blood transfusion than by continued dependence on plasma.

Reparative surgical management seeks to prevent contractures and excessive scarring by proper splinting and early skin grafting.

Unless complications develop, the initial dressing is not disturbed for 10 to 14 days.

The excision of devitalized tissue may be begun at this time. If this is associated with minimal blood loss, the area may be grafted immediately. More usually the wounds will be dressed again with fine mesh gauze and pressure dressings in anticipation of skin grafting 3 to 5 days later. The adoption of staged procedures in the removal of devitalized tissue is especially recommended for patients with extensive burns.

Systemic penicillin therapy should be continued until skin grafting is effected.

The hematocrit (or hemoglobin) value should be maintained by repeated transfusion of whole blood until all grafting has been concluded.

GAS GANGRENE

The bacteriologic demonstration of Clostridiums in a war wound is a minor contribution to diagnosis and clinical management. *Evaluation of the patient* and *examination of the wound* are necessary to distinguish between anaerobic cellulitis and clostridial myositis (gas gangrene).

Diagnosis.—Anaerobic wound infection should be suspected in battle casualties failing to respond to resuscitative measures. After initial surgery, the patient should be observed especially for pain in the wound, increasing pulse rate and disordered sensorium, either apathy or euphoria. In any suspected case the wound should be examined in an operating room with adequate light and instruments to permit thorough inspection and surgical treatment.

Anaerobic cellulitis is characterized by the septic decomposition of tissues devitalized by trauma. Gas and pus may infiltrate fascial planes. The pus may produce necrosis of the surface of tissue exposed in the wound but there is no extensive invasion of living muscle. The patient may show signs of nonspecific toxemia in association with wound putrefaction.

Clostridial myositis is characterized by the invasion and necrosis of living muscle tissue adjacent to the wound. The infection may be wet (edematous) or dry (emphysematous). The affected muscle is avascular, noncontractile and presents a variety of color changes. These findings are usually present in addition to those described for anaerobic cellulitis. The toxemia is more profound.

Predisposing factors are listed in relative order of importance:

1. Delayed or inadequate initial surgical treatment of the wound.

2. Interruption of arterial blood supply to a limb by trauma, thrombosis, ligation, or spasm.

3. Constrictive bandages, especially unsplit plaster casts.

4. Persistent circulatory failure and severe anemia.

5. Certain muscles derive their blood supply from one or two main sources. This is especially true for the gluteus maximus, hamstrings, rectus femoris, vastus intermedius and gastrocnemius. Special care should be exercised in the surgical management of wounds of these muscles in order to preserve the blood supply.

Prophylaxis.—The early application of sound principles of initial surgery is the most important factor in prophylaxis. Blood transfusion and penicillin therapy in selected cases supplement this program. The *wound should be left open* at the time of initial surgery. Prophylactic gas gangrene antitoxin is not recommended.

Treatment.—Anaerobic cellulitis responds to the secondary excision of devitalized tissue and the free incision of fascial planes. The same surgical procedure frequently will suffice to treat the infection and prepare the wound for later secondary closure. Clostridial myositis demands a more vigorous therapeutic program:

1. *Surgery.*—The most important factor in treatment is the prompt excision of all affected tissue. Local excision of a single muscle or group of muscles should be practiced in the interest of conservation of functional extremities. Amputation is advised for more extensive infection or where removal of the involved tissue implies loss of function of the limb.

2. *Resuscitation.*—The surgical excision of affected tissue contributes to resuscitation. Peripheral circulatory failure is frequently present, and whole blood transfusion is indicated. A severe anemia is usually present but hemoconcentration may occur in "wet" infections. Plasma is reserved for the correction of persistent hemoconcentration in selected cases. The demand for whole blood is considerable in the average case.

3. *Chemotherapy.*—Systemic penicillin therapy should be maintained in dosage of 200,000–400,000 units per day.

4. *Thrombophlebitis* is an established hazard of anaerobic infection. Pulmonary embolism contributes to the mortality rate in gas gangrene. Aspiration of trombi and vein ligation should be practiced at the time of amputation or during convalescence upon indication.

5. *Naso-gastric intubation* with suction is necessary to combat abdominal distention and gastric dilatation.

6. *Anuria* occurs with sufficient frequency to warrant especial consideration of fluid balance and urine volume. The exact mechanism of the anuria is not known. The vulnerability of the kidney to tissue anoxia secondary to protracted circulatory failure should not be forgotten.

7. *Gas gangrene antitoxin* is of doubtful therapeutic value. It is clinically impossible to distinguish the specific toxemia due to clostridial exotoxins from the nonspecific toxemia due to products arising from the septic decomposition of devitalized tissue. Current enthusiasm for therapeutic antiserum is restricted largely to the use of the trivalent serum containing antibody to the *Cl. oedematiens* toxin in the treatment of "wet" types of infection.

8. *Retroperitoneal cellulitis* and abscess may demand drainage early in the convalescence from gas gangrene.

CHEMOTHERAPY

No presently available chemotherapeutic agent can sterilize a contaminated or infected war wound. Neither penicillin nor the sulfonamides can prevent the ultimate septic decomposition of dead tissue or contaminated blood clots. Sulfonamides administered systemically are effective in the prevention and control of invasive hemolytic streptococcal infection but are ineffective in the control of staphylococcal or invasive clostridial infections. Penicillin is effective against hemolytic streptococci and staphylococci and, in addition, prevents the spread of clostridial infection from a focus of affected tissue. The effectiveness and limitations of chemotherapy are established sufficiently to attribute poor results to errors in surgical technic or judgment rather than to drug failures.

The concomitant use of sulfonamides and penicillin is unnecessary. The use of sulfonamides as a supplement to penicillin therapy contributes only the risk of untoward reactions and complications. There is no clinical evidence of synergism with the two agents.

The routine local use of chemotherapeutic agents has been abandoned. Penicillin may be instilled into serous cavities or major joints to complement the initial or subsequent surgical management of

injuries in these regions. Repeated dressing solely for the purpose of application of antibacterial agents contribute to persistent wound suppuration with aerobic wound pathogens.

Systemic chemotherapy is an adjuvant to the surgical management of a contaminated or infected wound. It does not offset the hazard of residual dead space or improper drainage.

WORKING RULES IN THE FIELD*

Combat troops should be instructed before battle to seek cover at once when wounded. They should try to drag or roll themselves out of the clear. Corpsmen should avoid going into open, exposed-to-fire areas except under great precautions of camouflage or in twilight. When available camouflaged dressings, dyed green, should be used. Bandages and slings may be smeared with dirt after application.

Avoid giving a lightly wounded man ½ grain of morphine, which may convert a walking wounded into a stretcher case.

Avoid the use of the tourniquet. It should be applied only if a pressure dressing, clamp, or ligature cannot be applied effectively, or if control of bleeding fails despite their use. A large spurting vessel should be clamped, and the clamp included in the dressing. The tourniquet may be used when the part of the limb distal to the wound must be amputated. Every effort should be made to get the patient with a tourniquet to a station capable of giving proper treatment within an hour.

A liberal application of sulfonamide powder in the depths of the wound should be attempted at the very first dressing, whether done on the field or at the first dressing station. The sooner sulfonation follows contamination of tissues, the less chance there will be of infection. Four grams of sulfathiazole or sulfadiazine should be given by mouth when the patient is first seen, 2 gm. 2 hours later, and 1 gm. every 4 hours thereafter for 5 days.

At the first dressing of the wound, when its character and disposition are ascertained, mask and gloves should be worn and aseptic technic with sterile instruments should be followed whenever possible. The introduction of new organisms after the initial injury should be avoided at all times. If a mask is not worn, as on the field, the mouth should be directed away from the wound when speaking.

The immediate treatment of a wound depends on elapsed time from injury, and on the character of the wound, whether still in a state of contamination or in a state of infection. The state of contamination has generally been considered as limited to the first 6 hours after injury, but the early, liberal, and effective use of the sulfonamides can prolong this period many hours. When the wound is in the state of contamination, cleanse wound thoroughly with copious amounts of sterile saline solution or boiled water. When suction is available, use tonsil sucker or large catheter inserted deeply into the wound, as this is a most effective method of removing infected blood clot, debris, and bacteria from the depths of the wound. Remove all loose bodies, bits of clothing, any foreign material, and unattached bone.

Do not *excise* wound. Do a "cleansing débridement" with sharp scissors, removing only obviously devitalized, badly traumatized tissue. Tie bleeders. Avoid tight packing of wound with gauze to control bleeding. If bleeding is due to tangential wound of large artery, ligate above and below the wound, and divide at the site of injury. If a badly contused artery gives evidence of early rupture, ligate above and below the wound, and divide. Ligation and division reduces the possibility of secondary hemorrhage by permitting retraction of the ligated ends. If the main artery to a limb requires ligation, ligate also the accompanying vein. The early development of a continuous thrill and bruit in a wound is indicative of an arteriovenous fistula. Do not operate hastily upon such a lesion. If absence of infection and decrease in local swelling permit, defer operation for 4 to 6 months to await complete disappearance of the swelling. Then danger of infection is minimal and the development of an adequate collateral circulation is completed.

If a nerve is divided, with or without loss of substance, approximate the ends as closely as fea-

* Prepared by Emile Holman, Comdr. (MC) U. S. N. R.

sible with several black silk or fine steel wire sutures applied in the perineural tissues. Apply plaster cast with the nerve in maximum position of relaxation by flexion of adjacent joints. This position is to be retained for 2½ to 3 weeks. A secondary operation may be necessary 6 to 8 months later because of failure of nerve union due to infection or to loss of substance. The subsequent approximation of nerve ends however will be much more readily accomplished if the above precautions are carried out.

After cleansing debridement, rewash the wound well with saline solution or water, and apply sulfonamide powder containing equal parts of sulfanilamide and sulfathiazole liberally to every possible portion of the wound. Spraying or "dusting" the exposed surfaces is not adequate. Make an emulsion in the wound by mixing the sulfa powder with tissue serum and blood, and smear this emulsion into every crevice of the wound with the gloved finger or with an instrument. If the wound is deep and the location makes it possible, make a counter incision in a nonvital area opposite the wound of entrance, and pull gauze heavily impregnated with sulfa powder through it. Never leave gauze or a tube in the wound as a through-and-through drain. Instead, introduce vaseline strips into each opening to the depth of the wound; these can then be spontaneously extruded as healing occurs. If possible, all raw and exposed surfaces of bone should receive a coating of the sulfonamide emulsion.

Introduce gauze strips thoroughly impregnated with vaseline or 5-percent sulfathiazole ointment, into the depth of the wound and likewise cover the side walls of the cavity. Do not pack the wound tightly. Fill in the space between the walls of the cavity with bulk vaseline or ointment. Cover the wound with gauze—not too amply—apply sheet cotton, or sheet wadding, and enclose in a plaster dressing. Use one layer of sheet wadding over the entire limb, two layers over bony prominences, and protect the heel adequately. Do not use skin-tight casts. Avoid voluminous dressings such as bulk cotton over wounded area, as this permits edema and herniation of raw tissues beyond the surface of the skin. Do not cut window in casts. Do not dress wound after cleansing debridement unless fever, broken cast, poor reduction of fracture, or excessive soiling of cast demand it. Include thin metal strips, thin wooden strips, or basswood splints soaked in water, to strengthen the cast at points of stress, and to conserve plaster.

Gunshot wounds of the extremities that shatter the bone usually have a paralyzing effect upon the surrounding muscles. Hence reduction is surprisingly easily accomplished without much manipulation and with moderate traction by simply alining the normal control points; big toe, patella, and anterior superior spine, and applying a plaster cast. Avoid unnecessary motion at site of fracture during application of cast by first applying a fairly heavy posterior splint of plaster, mold this to limb in position of reduction, permit it to harden, and then apply circular plaster bandages.

Avoid separation of fragments through excessive traction. This is important also in the application of Thomas splints in the field. The object of these splints should be immobilization, not primarily reduction.

Avoid overtight clove hitch traction to the bare or booted foot. Subsequent amputation has been found necessary because of gangrene precipitated by a clove hitch too tightly applied and subjected to excessive traction in the field where continuous observation is impossible.

While casts applied to elbow and forearm, or to thigh and lower leg, are still wet, split them down the center anteriorly, cutting the plaster down to the sheet wadding or stockinette. If evidence of circulatory embarrassment appears, such as syanosis, swelling, coldness or numbness of the toes or fingers, immediately spread the cut edges of the cast even more widely, and divide all material down to the skin. Failure to heed these signs leads to gangrene or Volkmann's ischemic contracture.

When plaster dressing has been completed, indicate the site and size of the wound and draw a picture of the fracture on the cast with indelible pencil. Indicate also division of nerve or tendons, or major artery when present. State date of application of the cast.

Splint or immobilize with plaster all extensive injuries to soft parts even in absence of fracture of the bone. Injuries to soft parts around the shoulder should be dressed with arm well elevated, the arm to be held in this position by shoulder spica or by airplane splint. This prevents disabling contractures of axillary tissues.

Never close a wound completely. Generally speaking, all wounds are better left widely open except wounds of the face. Exposed joint surfaces and exposed tendons should be covered by skin flaps whenever possible, after thorough cleansing and sulfonization.

All amputations should be guillotine in type. All viable skin and bone should be saved. No sutures are necessary nor are they desirable. Apply sulfonamide powder liberally to the bone, and to the site of ligation of vessels. Introduce one vaseline strip down to, but not touching, the bone end, and cover raw surfaces with vaseline or sulfathiazole ointment gauze.

Never apply dressing to amputation stump with stump *elevated,* rather apply dressings and bandage or cast to the stump with the affected arm or leg hanging over side of table in a dependent position. Gravity pulls muscle and skin over the bone stump, and when bandaged in this position, the maximum covering of the bone is attained. Immobilize in extension by a plaster dressing the joint proximal to the amputation. Apply a posterior molded splint of plaster so as to project beyond the end of the stump about 2½ to 3 inches. Let this harden and apply circular plaster bandages. Apply hip spica for thigh amputations with the head of the table elevated to make stump dependent. If the cast cannot be employed immediately, do not permit a thigh amputation stump to be elevated on pillows; this pulls the adjacent soft tissues away from the end of the bone. A thigh stump should lie flat on the bed, and the head of the bed should be elevated on blocks to permit the soft tissues to fall over the bone end. This will permit gravity traction during the period before skin traction can be applied.

Plaster immobilization of an amputation stump with proximal joint in extension will prevent: (*a*) Trauma to stump; (*b*) infection; (*c*) possible secondary hemorrhage; (*d*) flexion contractures. After application of cast do not dress the stump unless fever or definite indications demand it. Patient should be made ambulatory, on crutches if necessary, as soon as his general condition permits. After 2 to 3 weeks, remove cast and apply skin traction. Adhesive strips applied to the skin on four sides of the stump should project well beyond the end of the stump in order to permit fashioning from them a small well in which weights may be carried to maintain constant traction even though the patient is ambulatory.

Gas Gangrene.—The mere presence of gas bubbles in tissue as demonstrated by roentgenograms is not evidence of gas bacillus infection. They may be due to air carried in by the projectile, or due to non-pathogenic gas-producing organisms. True gas gangrene is a rapidly progressive, spreading infection, characterized by abrupt rise in temperature, rapid pulse, severe toxicity, severe local pain and tenderness, mouse-like odor, bronze discoloration of skin, and crepitus. If diagnosis is established by clinical evidence and by study of smears from the wound: (1) Give double therapeutic doses of polyvalent gas gangrene antisera intravenously; (2) give full dosage of a sulfonamide, by mouth, or intravenously, or by rectum; (3) excise wound widely and completely, removing all necrotic tissue and foreign bodies, and excise completely any muscle that shows evidence of being partially devitalized; (4) apply liberally local sulfonamides; (5) obtain wide-open drainage with vaseline strips, and (6) immobilize. Amputate only if infection is spreading rapidly, or if blood supply to extremity is obviously badly impaired.

When a wound is first seen in a state of positive infection, operative treatment must be limited to removal of detritus and foreign bodies. If possible do not produce bleeding in the wound, do not irrigate, do not break down the natural defense barriers set up by the body, by rough handling of tissues, by excessive exploration of wound, or by unnecessary manipulation of the wounded parts. Remove foreign material, introduce sulfonamides and vaseline strips to all pockets of the wound and immobilize in plaster whether fracture of the bone is present or not. Provide sulfonamides by mouth, and do not dress wound unless positively indicated by persistent fever, pain, or failure to improve.

A badly infected joint is a serious menace to life, particularly an infection of the knee joint that begins to spread upward in the muscle planes of the thigh. A septic knee joint may be more adequately drained by removal of the patella. If a septic knee is accompanied by a well advanced general sepsis, an early thigh amputation is necessary to save life.

Causalgia, a severe, persistent, neuralgic-like pain producing an apprehensive, sick patient with red,

shiny skin and atrophy of the affected part of the extremity, is a frequent complication of peripheral injuries, most probably due to involvement of the sympathetic nervous system, reflexly or directly. Repeated paravertebral injections with novocain of the lumbar sympathetics in lesions of the lower extremity, and of the inferior cervical and superior thoracic ganglia in lesions of the upper extremity, are most effective in allaying this agonizing pain.

Foreign Bodies.—Accessible bullet and shrapnel fragments should be removed at the time of cleansing debridement. If a foreign body lies far remote from the immediate wound, a second incision for its removal may be necessary but should be deferred until later, unless it lies very superficially. Foreign bodies in constantly moving tissues such as a joint capsule, or if imbedded among tendons, as at the wrist, or in the movable structures of the neck, or if located in perineural tissues, should be removed early to avoid disabling fibrosis and distal paralysis by fibrous constriction of the nerve. Jagged foreign bodies lying near large vessels should be removed early to avoid danger of erosion by motion or by infection. Great care must be exercised in withdrawing a jagged sharp foreign body along a path in which important structures such as main vessels and nerves lie. A second incision permitting withdrawal in the opposite direction is preferable.

To avoid subsequent embarrassment at the operating table, the surgeon who expects to remove a foreign body should be present at the fluoroscopy undertaken to determine exactly the intersection of the three planes in which the foreign body lies, these planes to be clearly marked on the skin with the body in the position to be assumed later on the operating table.

Burns.—The use of massive plasma infusions and salt solution by vein is axiomatic. Avoid tannic acid or any escharotic agents. Apply a thin coating of sulfonamide powder by spray. Apply gauze heavily impregnated with vaseline, or 5-percent sulfathiazole ointment, cover this ointment gauze with oiled paper to prevent absorption of the ointment by overlying dressings, apply fairly voluminous dressings and a pressure bandage. Do not disturb for 10 days unless fever demands it. Begin a sulfonamide immediately by mouth. If the patient is vomiting give the sulfonamide intravenously, or by rectum (4 gm. sulfanilamide emulsified in 100 cc. of water introduced by catheter into rectum every 8 hours).

All dressings for burns must be applied with joints in full extension to avoid skin contractures. However, a badly burned hand should be supported in the neutral position of moderate flexion of fingers and slight dorsiflexion of wrist. In burns involving the axilla, it is most important to apply vaseline gauze, oiled paper, and bandage with arm well elevated. Only after this precaution may the arm be brought to the side of the body.

When the patient is no longer in transit, and has reached a hospital where continuous care can be administered, the repeated frequent application of paraffin wax by spray is the least painful and a most efficacious treatment for burns.

Thoracic Wounds.—Immediate marked dyspnea in the presence of a nonsucking wound of the thorax is probably due to pressure pneumothorax or to hemothorax. If signs point to pneumothorax, put in a needle and withdraw air; if air reaccumulates promptly, leave the needle in place, attach a rubber tubing, and place the other end under water. If subcutaneous emphysema appears in the neck above the suprasternal notch in the presence of marked respiratory embarrassment, a mediastinal emphysema is probably present. A short incision in the suprasternal notch will permit the escape of air, and may be life-saving.

A hemothorax should be aspirated—*without* replacement with air—only if dyspnea or mediastinal shift demand it. If hemothorax or evidence of effusion persists 2 to 3 weeks, partial aspiration—*without* replacement with air—is indicated. When possible study the aspirated fluid by culture and by determining red cell, white cell, and hemoglobin content. When repeated aspirations are found necessary, comparison of these studies will yield important information as to future care.

Jagged wounds of the thoracic wall should be well debrided, liberally treated with sulfonamide powder and loosely closed to avoid infection which may extend to an underlying hemothorax with disastrous results.

Sucking wounds must be closed immediately. If operation is not possible, cover wound with a sterile glove or sterile cellophane, or gauze heavily impregnated with vaseline or with 5-percent sulfathiazole ointment. A pad is then applied and

fixed in place with adhesive straps completely encircling the chest. The operative closure of a sucking wound may require semilunar incisions in muscle, or if muscle is not available, semilunar incisions in the skin, enabling it to be drawn over the defect, the resulting raw surfaces subsequently to be epithelized by skin-grafting.

Abdominal Wounds.—Immediate operation is indicated in any perforating wound of the anterior abdominal wall, whether evidence of peritonitis exists or not. Operate through an incision independent of the wound. Debridement of the traumatic wound is to be done at the end of the operation. Wounds involving the mesocolon or mesentery of the small bowel, producing large retroperitoneal extravasations of blood in presence of a perforating wound of the bowel are particularly dangerous to life from subsequent peritonitis. Under these conditions a Mikulicz procedure is indicated when feasible. When this is not possible as in the distal pelvic colon or rectum, a complete colostomy proximal to the repaired area is absolutely necessary. Simple perforations of the bowel without retroperitoneal extravasations may be closed by suture without the performance of a colostomy. Continuous gastric suction by in-dwelling Levine tube should be immediately provided in all abdominal wounds.

Large wounds of the liver, following careful cleansing and sulfonamide application, must be drained, preferably through a separate stab wound. Oozing may be controlled by applying to bleeding points, muscle fragments obtained from the incision in the abdominal wall.

Urinary extravasations are exceedingly dangerous to life. If bladder or urethral injuries are suspected as evidenced by hematuria, absence of urine, lower abdominal tenderness and swelling, immediate suprapubic cystostomy for urinary drainage is absolutely indicated.

Head Injuries.—Wounds of the face require cleansing with soap and copious amounts of water, minimal debridement with conservation of all skin and tissue possible, liberal sulfonamide application and accurate approximation of skin edges. Jagged wounds of the cheek with loss of considerable substance should not be closed under tension. It is preferable to approximate mucous membrane to skin along line of laceration, leaving open defects into the mouth, which can be closed later by plastic revision.

Do not remove any fragments of the lower jaw still attached to the periosteum or to surrounding tissues. Maintenance of contour of jaw during the healing process is most necessary.

Frontline treatment of head injuries without laceration of scalp consists of rest in recumbent position, and as little and as gentle transportation as possible. Do not give morphine unless other associated injuries demand it. If bloody fluid is leaking from an ear, plug lightly with cotton. Record briefly the neurologic examination; size and equality of pupils, facial symmetry, right and left muscular or sensory disturbance, and presence or absence of superficial and deep reflexes.

Lacerations of Scalp.—Determine if skull is intact by inspection, or palpation with gloved finger or sterile instrument. Shave the surrounding area if possible. Cleanse thoroughly but gently. Perform minimal debridement of obviously nonviable tissue. Frost lightly with a sulfonomide powder. Approximate wound edges with adhesive strips or with not more than two or three loose sutures. Apply a secure dressing. If uncertain about integrity of skull, leave the wound open.

Penetrating wounds and compound skull injuries are treated in the same general way but are always left open. Optimum time for definitive treatment is dependent upon availability of adequate surgical and radiologic equipment. Be careful in moving large or depressed pieces of bone or metallic fragments. They may tampon large vessels. If foreign bodies do not lift out easily leave them alone. Do not poke or scrape around exposed brain. Do not use strong antiseptics such as tinctures or alcohol. Cleanse gently with soap and water. Frost exposed brain with sulfanilamide; not sulfathiazole as it produces fibrosis. Apply vaseline gauze and a dressing that will stay on. Elevate head of cot or stretcher. Begin systemic sulfonamide at once, by mouth if possible, otherwise by vein, or by rectum.

CHAPTER 5

FIELD SANITATION

WASTE DISPOSAL

Purpose of Waste Disposal.—The proper disposal of waste materials is one of the important measures for the control of the intestinal and insect-borne diseases.

1. Waste disposal must accomplish the following:

a. Destruction or the safe disposal of material which may contain pathogenic organisms.

b. Destruction or prevention of breeding insects and rodents that spread disease.

c. Removal or prevention of conditions offensive to the senses. Classification of waste.

2. The wastes to be disposed of may be classified as—

a. Human excreta (feces and urine).

b. Liquid waste or sewage (scullery, galley, bath, laundry and flush toilet wastes).

c. Refuse (garbage and rubbish).

Responsibility for Disposal.—The commanding officer is responsible for sanitation within all areas under his jurisdiction. He issues the orders and provides the personnel necessary to assure sanitary disposal of wastes. When wastes must be transported and disposed of outside the area under his jurisdiction the commanding officer will make sure that no health hazard is created and that the disposal of waste will not interfere with subsequent expansion of military operations.

Prior to combat operations the senior medical officer recommends a program for sanitary waste disposal suitable for the proposed operation. The program shall include plans for indoctrination of officers and men, plans for obtaining, loading and unloading knockdown equipment, and plans for setting up waste disposal facilities at the earliest possible moment and for their proper operation and maintenance. The medical officer shall consult with the commanding officer and the Public Works engineer officer as necessary to assure that the proposed program can be effectively executed. He must prepare for the approval of and issue by the commanding officer, the sanitary orders required to carry out the program.

Prior to and during combat operations the medical officer must do the planning and make all arrangements necessary to assure proper disposal of wastes. He is the key member in the three man team, commanding officer, medical officer and engineer officer. However, when the development of a permanent or semi-permanent base or camp is undertaken, the more complicated nature of waste disposal facilities needed requires that the engineer or public works officer assume the job of planning and building sanitary works. The engineer then becomes the key man who advises the commanding officer after consultation with the medical officer. This shift in responsibility must be clearly understood and agreed upon in the field. In any case the medical officer will inspect the operation and maintenance of waste disposal systems insofar as these affect the health of personnel and will advise the commanding officer concerning the need for improved operation or for additional facilities.

The Public Works officer or the Marine Engineer Battalion officer is responsible for the planning, design, construction, operation and maintenance of waste disposal systems in all established shore based

activities. As described above, when an occupied area is to be developed into a semi-permanent camp or an advanced base, the engineer or Public Works officer shall take over from the medical officer, by definite agreement between the two and the commanding officer, the responsibility for advising, planning, building and operation of waste disposal facilities.

Human Excreta.—On the march or during temporary encampment, the simplest possible sanitary methods of waste disposal must be utilized. If an occupied area is to be used for establishment of a semi-permanent base, the sanitary facilities must be improved as rapidly as possible. Well developed advanced bases may have sewage and waste disposal systems comparable to those of an American city.

Emergency Disposal.—During brief halts on the march, or on initial landings, men who desire to relieve themselves should dig a hole with an entrenching tool or bayonet, and after depositing feces should cover them with several inches of earth. All men should carry a supply of toilet paper with them in the field. During a halt for a meal a sanitary detail should be assigned to dig latrines immediately. Narrow trenches 8 inches or more in depth and 1 foot wide suffice. These should be confined to as small an area as possible and their location should be pointed out to the men before they fall out after the march. Noncommissioned officers should be held responsible for policing, or a guard should be posted to make sure these facilities are used properly. When the column is again on the march, the sanitary detail remains to fill in the trenches with earth and mark their location.

LATRINES

Latrines should be located adjacent to the company area. They are generally a company installation and are maintained by the respective companies. Latrines should be located on the side of the camp area opposite the galley and mess hall. Drainage from the latrine into a source of water supply should be avoided. Latrines should be located on well drained ground and protected by a ditch which will prevent flooding or damage during heavy rain storms. On small islands latrine locations should be limited in number and carefully selected to avoid interference with future development of the camp area available. A sufficient number of latrine seats or spaces should be installed to provide 1 seat for each 10 to 20 men; depending on the size of unit. Separate latrines should be constructed for officers and for enlisted personnel. A lighted lantern can be hung at each latrine at night unless military situation demands concealment. When pits are filled to within 18 inches of the ground surface or are to be abandoned, the pits should be thoroughly sprayed, the excavation backfilled, the surface mounded over to allow for future settlement, and the military situation permitting, should be placarded showing the date and organization.

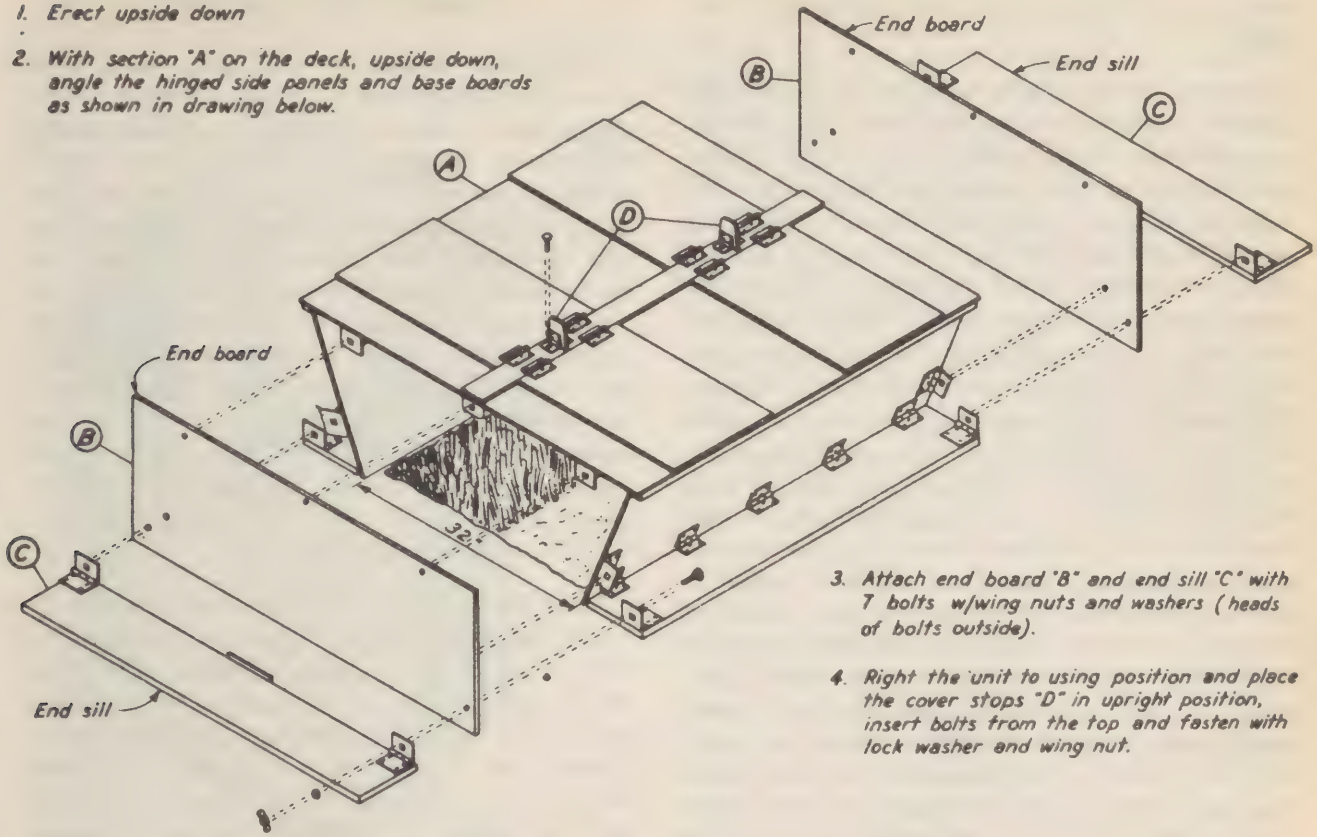
Straddle Trenches.—Straddle trenches are used in bivouac, in camps of less than one week duration, or until deep pit latrines can be constructed in camps of longer duration. The straddle trench is constructed by digging a trench 1 foot or less in width, 2 feet deep and 3 to 10 feet long. Adjacent trenches should be 3 feet apart. The earth removed should be piled at the ends of the trench, leaving a foothold on each side which can be improved if necessary by planks. A can or shovel, placed on the piles of earth, must be used by each man to cover his excrement. Toilet paper should be protected by cans or canvas during rainy weather. In inhabited localities the trenches should be screened from vision. Straddle trenches should be sprayed daily. Before camp is broken or when trenches are filled within one foot of the ground surface, they should be sprayed, filled and mounded over with earth.

Deep Pit Latrines.—Deep pit latrines are used in temporary camps and may be used on bases of a semi-permanent nature. Great care must be exercised in their construction and maintenance, otherwise the latrine will be a menace to health.

A fly-tight box is an absolute necessity. It may be made *knockdown* in type, assembled and stored prior to use and after use may be taken apart and easily moved. A prefabricated portable latrine box developed by the Marine Corps is shown in Figure 39. The box folds and is light enough to carry ashore during landing operations. It can be erected very quickly without the use of tools. The 4 hole unit may be bolted end to end to provide latrines with any multiple of 4 seats. The pit for

1. Erect upside down

2. With section "A" on the deck, upside down, angle the hinged side panels and base boards as shown in drawing below.

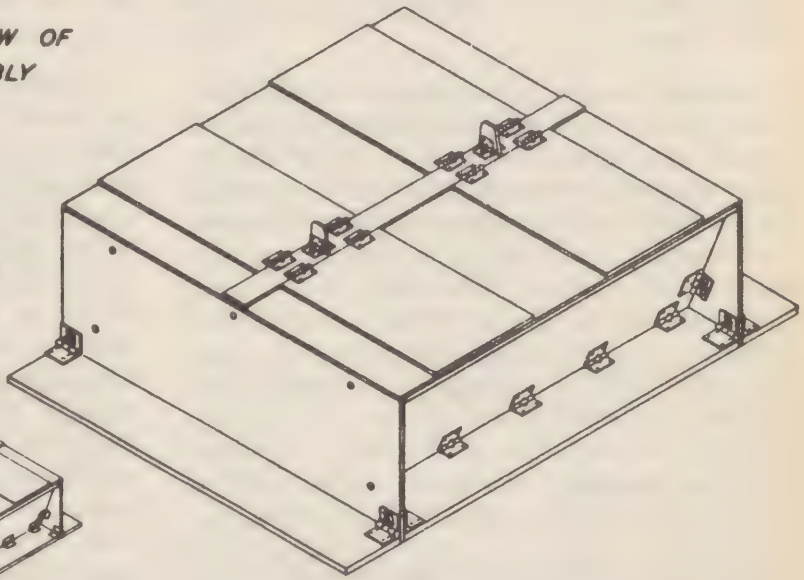


3. Attach end board "B" and end sill "C" with 7 bolts w/wing nuts and washers (heads of bolts outside).

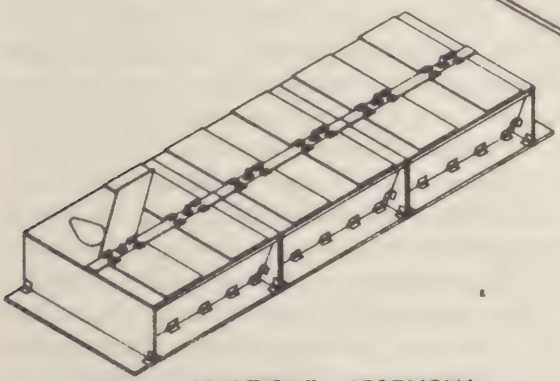
4. Right the unit to using position and place the cover stops "D" in upright position, insert bolts from the top and fasten with lock washer and wing nut.

EXPLODED VIEW OF UNIT ASSEMBLY

When two or more units are to be used together, assemble the units as above with the exception of the sections "C" where they join (these sections discarded). Bolt the adjoining sections "B" and channel irons (part of these bolts must be fixed working within the openings-lids up)



ASSEMBLED UNIT



MULTIPLE ASSEMBLY

Figure 39.—Portable latrine field assembly.

these boxes should be 32 inches wide by 4 feet long.

A latrine which is to be used less than one week should be dug 3 feet deep. One foot depth should be added for each additional week of anticipated use. Field tests have shown that in ordinary soil bacteria can travel only a very short distance from the pit, even when the pit penetrates the ground water. Where the ground water flows through very porous gravel or in open cracks, crevices and caverns in limestone, coral or volcanic rock penetrated by the pit, ground water pollution may be serious. Fly breeding is prevented and digestion of solids is improved by using deep pits penetrating well below the water level in the ground. A clam shell bucket is useful in excavating such pits. If soil near the surface is loose or sandy, as is ordinarily the case, pits have to be cribbed with poles or planking to prevent cave-ins. Oil drums with one or both ends removed make excellent cribbing. If possible, one drum should be used under each seat. Pits may be constructed by blasting a hole, then setting in and backfilling around the crib. If ground water is very near the surface a crib may be set up on the surface and a bulldozer used to mound soil around it. An elevated pit latrine results.

Where fly breeding is not prevented by the depth of the pit or by the use of chemicals, the ground around the pit must be treated to prevent the escape of larvae. An area 4 feet wide surrounding the pit should be excavated to a depth of 6 inches, then covered with burlap or similar material soaked with crude oil. This burlap should hang down the walls of the pit 18 inches and should be turned down into the ground at the outer edge. The earth should then be replaced, tamped down, and more oil added. If burlap is not available, oil alone may be used. After the latrine box is placed over the pit, oiled or moistened earth should be tamped tightly around the perimeter of the box.

The latrine should be enclosed from view by a screen made of canvas or other material and if possible protected from the rain by the use of a tent or other covering. If enclosed, provision should be made for ventilation, with all openings made insect proof. Doors should open outward. A drainage ditch at least 6 inches deep should be dug around the latrine enclosure and connected with a drainage channel to carry off surface water.

OTHER TYPES OF LATRINES

Pail latrines should be used only where it is impossible to construct a pit, for example, where the ground is flooded or frozen. A pit type latrine box may be adapted for use as a pail latrine. Strips are nailed to the floored box to spot the pail and a metal deflector provided to direct urine into the pail. When located in a building, the latrine should be arranged so that the pails can be removed from the outside of the building through hinged openings in the wall. The pails should contain about 1 inch of a 2% cresol solution, and they should be removed at least twice daily and be replaced by clean pails. The excreta may be disposed of by burial or by dumping into a sewer system. Pail latrine systems are difficult to maintain in a sanitary condition.

Bored-hole latrines have been used extensively in the far and middle east. These consist of a round hole, 14 to 18 inches in diameter and 15 to 20 feet deep made with a post-hole auger. This type of latrine has the advantage of being almost flyproof due to its depth. A temporary flyproof cover may be used with the hole latrine, or a seat may be installed. If conditions warrant, a permanent structure should be placed over the latrine.

Urine Soakage Pits and Trenches.—Separate soakage pits or trenches should be used to dispose of urine. The pit shown in Figure 40 will dispose of the urine of 200 men. This pit is about 4 feet square and 4 feet deep and filled with pieces of broken stone (1 to 4 inches in diameter), flattened tin cans, brick or broken bottles. Ventilating shafts should be provided to aid oxidation and hence minimize odor production. These should extend from about 1 foot above the ground surface to within 6 inches of the bottom of the pit. The upper end of the shaft should be screened and the part below ground should contain holes for ventilating the rock. Crushed stone should be covered with oil soaked burlap and then covered with earth. Soakage trenches are suitable where soil near the surface will absorb urine and where it is not desirable or possible to excavate to a 4 foot depth. They consist of a central pit 2 feet square and 1 foot deep with trenches radiating from each corner. These are 1 foot deep and 1 foot wide at the pit and slope to a depth of 18 inches at the outer ends. Length of trenches is usually about 6 feet but may be longer, if required. As in the case

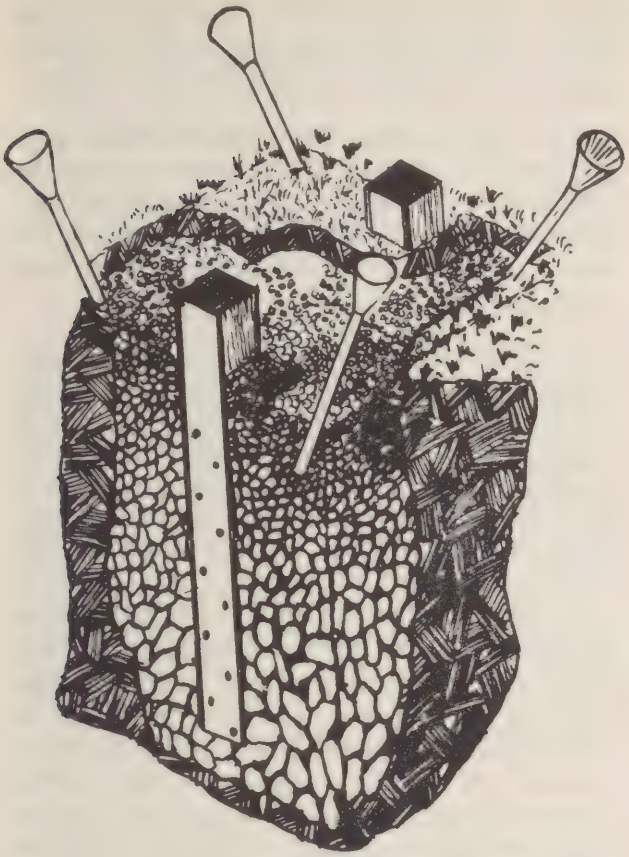


Figure 40.—Urine soakage pit.

of soakage pits, trenches are filled with broken stones, bricks, etc., then surfaced with oil-soaked burlap and covered with earth. When the soakage pits or trenches are abandoned, all appurtenances should be removed and the openings filled with earth.

When the soil is pervious or can be made pervious by blasting, it will serve as a natural urine soakage pit without further preparation. Urinal piping should extend at least 1 foot into the pervious material.

Urine Trough and Funnel Connections.—Urine troughs may be mounted directly above soakage pits or may be erected in an adjacent enclosure and connected to the pit by means of suitable piping. If a latrine pit is located in unusually porous ground, troughs may be connected thereto in lieu of constructing separate urine pits. However, urine in the latrine pit causes offensive odors so should be kept out if possible.

A urine trough may be constructed of tinned or galvanized iron, or of wood. If made of wood, it should be lined with tar paper and made water tight. The trough should be "U" or "V" shaped in cross-section and sloped toward the outlet so that it will drain completely. The outlet should be protected by a wire mesh insert to prevent foreign material from entering and clogging the drain piping. Length of trough should be approximately 10 lineal feet per 100 men.

Where the facilities are for 50 men or less, connections to the pit may be a 2-inch drain pipe terminating at the top in funnel inlets. Funnels may be of metal or tar paper. They should be protected against clogging by a wire mesh insert or filled with grass or straw.

Night Urinals.—If the distance to the latrine is considerable, a large can or pail containing 1 inch of cresol solution should be placed close to the living quarters. A simple type of night urinal can be improvised by making a hole in the center of the top of a garbage container and placing the inverted top over the garbage can. Each morning the contents of the can should be poured into the soakage pit and the can cleaned and sunned during the day.

Maintenance of Latrines and Urinals.—Latrines, urine troughs and pails must be maintained in a sanitary manner. To insure this condition a latrine orderly should be placed in charge. The following are particularly important:

a. Keep the box fly tight.

b. Keep the lids closed.

c. Scrub the seats and urine troughs daily with soap and water and twice weekly with a disinfectant.

d. Treat the pit with PDB, or spray with sodium arsenite or with DDT twice weekly or spray the pit with oil daily. Burn out the paper twice weekly. To do this sprinkle the contents with a little kerosene or diesel oil (not gasoline) to give a low fire when ignited.

e. Do not contaminate the seats with oil or poisonous insecticide solutions used to treat the pit.

f. Supply ample toilet paper.

g. Use fly traps when indicated.

Control of Fly Breeding in Latrines.—The following treatments have been used with success to reduce or prevent fly breeding in the ordinary type pit latrine.

Paradichlorobenzene (PDB), ¼ inch granular.—Add 8 pounds initially to an 8 seat latrine and 2 to 2½ pounds twice a week thereafter. The chemical forms a layer of gas which acts as a larvicide and keeps adult flies out of the latrine. This method requires no equipment, is cheap and highly effective. Stock No. is 51D193, Dichlorobenzene, para, 200 lb. drums.

Sodium arsenite solution.—Spray the pit twice weekly with a solution consisting of concentrated sodium arsenite powder dissolved in 100 gallons of water. Stock No. Penite-6 or equivalent is 51S2333, Sodium arsenite, 54% solution, 30 gals. drums.

Sodium arsenite formula.—Mix 4 lb. sodium arsenite, 2 quarts of molasses or equivalent sugar solution and 40 gallons of water. One gallon of this solution is sufficient to treat an 8 seat latrine.

Fly Sprays.—Standard fly sprays may be used to spray the pit, the latrine box and the hut or shelter at regular intervals. The active ingredient of these sprays is either DDT, pyrethrum, Lethane or other insecticide. Of these DDT is preferred because of its residual action. A surface wetting spray of 5% DDT in kerosene should be used.

Oils.—The pit contents, the inside of the box and the ground around the latrine may be oiled daily to keep down fly breeding. Latrine oil should consist of 3% cresol in diesel oil or in a mixture of kerosene and fuel oil.

Chemical Toilets.—Chemical toilets offer a sanitary method of disposal. Operation of this type of toilet depends upon the action of caustic soda and water, which not only kills all the bacteria but also liquefies some of the solids. The tank is charged with 25 pounds of caustic soda for each seat and is filled with water to above the lower edge of the drop-tube, and agitator and manhole shafts. This forms a water seal and prevents escape of odors. After use, the lid of the bowl should be closed and the agitator operated several times in order to mix chemical and excreta. Proper charging with caustic soda, maintaining a high enough water line to form a seal, and agitating after use are essential for good operation. The period of use before emptying and recharging becomes necessary should be several months; will probably be less.

If no gravity drain is provided, the tank must be emptied by bailing or pumping. At some advance bases a tank truck equipped with a pump is assigned to this duty. The contents should be buried or barged to sea. Wastes from a chemical toilet must not be placed in septic tanks.

Waste Water Flush Type Facilities.—The most sanitary method of removing human wastes from the vicinity of habitations is flushing into a sewerage system. However, flush type toilets are frequently not available on advance bases or the supply of water is too limited to be used for flushing toilets. The waste water automatic flushing latrine is suitable under these conditions. In this latrine waste water, shower and lavatory, is used to flush the excreta from the channel under the latrine box. When a 225-gallon dosing tank is filled by flow from the showers and lavatories, an automatic siphon discharges the tank contents into the latrine channel. The flushing action of the water carries the excreta into the sewer system. A dam near the outlet end retains about 5 inches of water in the channel at all times. A latrine of this type could be improvised using almost any type of building material. Standard design details appear on Y&D Drawing No. 283,369.

Liquid Waste or Sewage.—Liquid waste or sewage includes water from showers, lavatories, galley, scullery, and also from flush toilets, whenever installed. The amount of water used in these facilities determines the quantity of sewage to be disposed of. Where the volume of waste is small and the soil is pervious, sewage may be passed through settling tanks and disposed of by absorption in the soil. As water supply facilities are enlarged, water consumption, and hence liquid waste, increases to a point where it cannot be disposed of in this manner. Under these conditions a system of pipes or sewers may be required to convey the waste liquids to a point where they can be disposed of into a natural body of water. When required, sewage must be treated or altered so that it may be disposed of without creating a nuisance or menacing health.

Grease Traps.—Liquid wastes originating in the galley or scullery contain a large amount of fat or

grease. This congeals upon cooling and clogs drain lines and absorption areas, and causes excessive scum formation in settling tanks. For this reason wherever possible galley and scullery wastes should be disposed of by a system which is entirely separate from systems used for disposal of other wastes. Grease traps must be installed ahead of disposal facilities involving absorption into the soil. Grease traps may be of the baffle or filter type.

Baffle Type.—The baffle type grease trap may be improvised from an oil drum or wooden barrel or may be made of concrete, steel or wood. (See Figure 41.) A flyproof cover is essential. A baffle extending to within several inches of the bottom divides the container into unequal chambers, the larger being the grease chamber. The outlet should be placed about 8 inches below the upper edge of the container, and the inlet should be 4 inches above the outlet. When warm galley waste mixes with the cooler water in the trap, the grease congeals and rises to the surface where it is retained by the baffle. Cooling is improved by sinking the trap into the ground. Grease traps are usually too small.

The congealed grease or scum should be skimmed daily and buried or burned with wood. The grease trap should be completely emptied and scrubbed with soap and water when odors begin to develop or when the bottom sludge has reached a depth of a few inches. Liquid wastes containing fecal matter should never be passed through a grease trap.

Filter-type.—The function of this trap is to strain or filter out grease and other matter which would readily clog the soil. The filter is generally constructed from an oil drum or wooden barrel with the upper end removed. The bottom is perforated and the drum is filled with 6 inches of gravel or crushed stone followed by 18 inches of coarse sand, wood ashes or coral. If the liquid waste has not been previously strained to remove the coarser particles, a burlap covering should be placed over the top of the barrel for this purpose. A basket type strainer can be constructed by perforating the bottom of a pail or other metal container and filling it with grass, hay or straw. The filter and strainer media must be removed and replaced as soon as they become clogged. Burlap strainers should be washed daily. Used filter or strainer material should be buried or burned to prevent nuisance.

SEWERS

Design.—Sewers are usually constructed of vitrified clay tile, concrete or cast iron pipe. They should be laid on slopes which will provide self cleaning velocities of 2 to 3 feet per second. The joints should be carefully sealed to prevent leakage from the sewer or seepage of ground water into the sewer. Manholes are constructed at the upper end of each lateral, at each change in direction and grade, at sewer junctions and at not more than 400-foot intervals on straight runs. Sewage is carried through manholes in open channels formed into the concrete manhole bottoms. Sewer pipe should always be laid on firm foundation in a

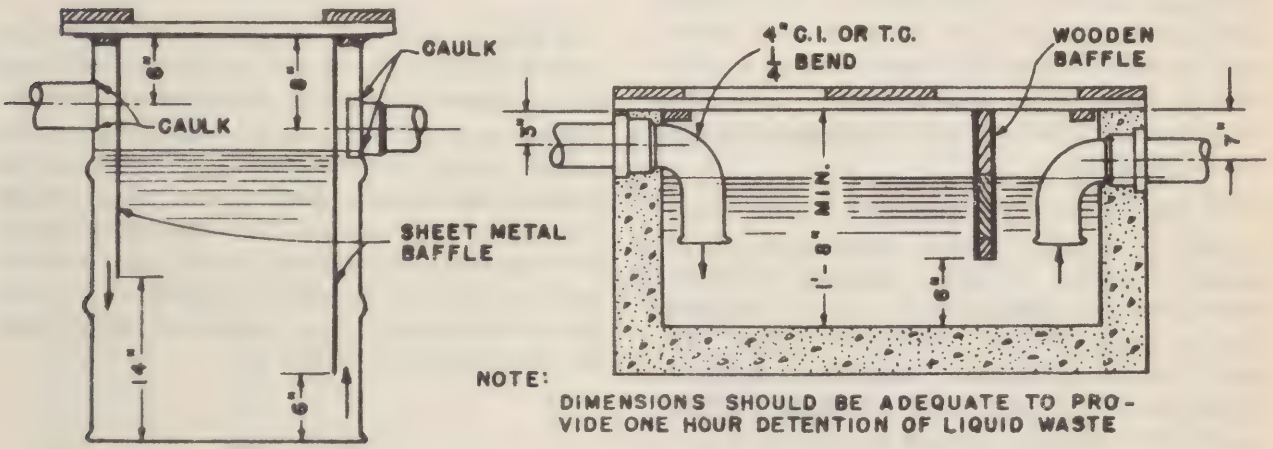


Figure 41.—Grease traps.

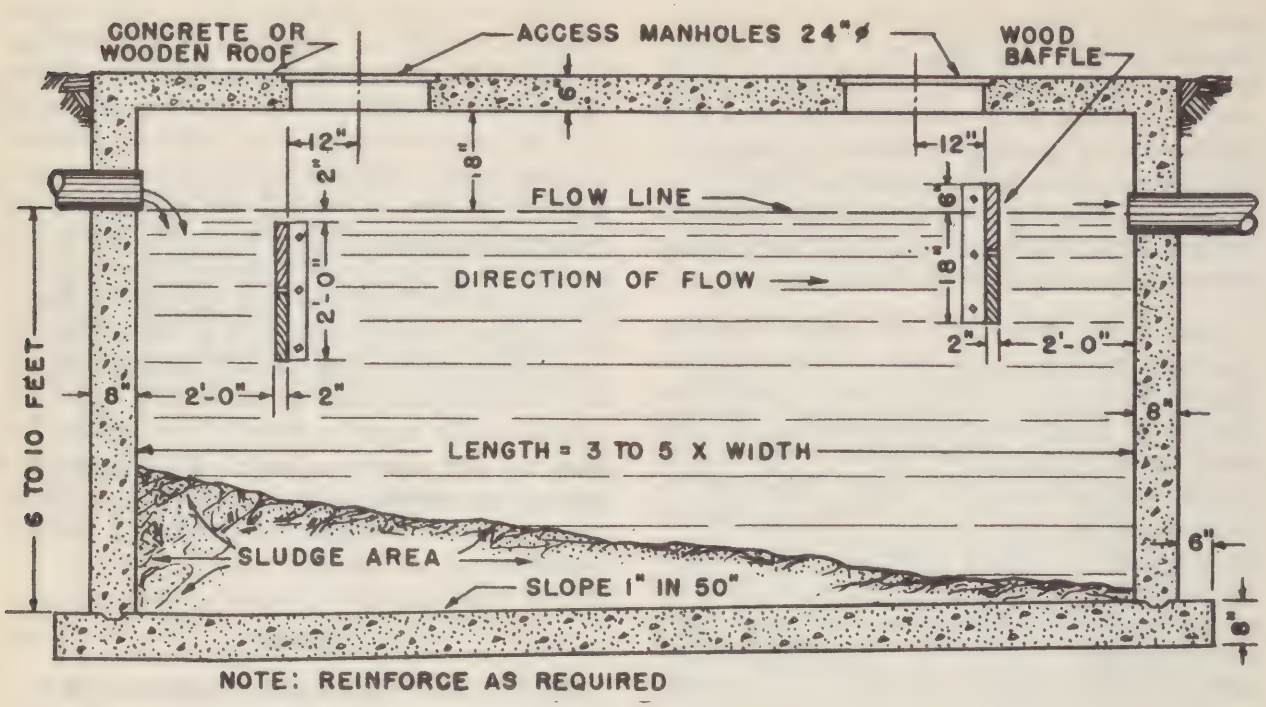


Figure 42.—Septic tank.

straight line and on a uniform gradient and should have 4 feet or more of cover to provide protection from traffic and frost. Sewers should be maintained in proper operating condition. A lamp and mirror are useful for inspecting sections of sewer between manholes.

Concrete Pipe Forms.—Forms to fabricate concrete pipe are now available for advance base use. These will permit wider use of the sewer system as a method of disposal of liquid waste. Stock forms include 6″, 10″, 18″ and 24″ diameters but other sizes can be obtained. Joints are of the tongue and groove type and can be made with cement mortar. Where fresh (not septic) wastes are handled, no surface protection is required. Sewage can be maintained in a fresh condition by using proper sewer gradients.

Settling Tanks.—A settling tank is a basin, usually reinforced concrete, through which sewage is directed to remove settleable material. Sedimentation of sewage is a partial or preliminary treatment used to remove the gross suspended matter. Effective removal of settleable material is dependent upon time of retention and maintenance of uniformly low velocities throughout the entire cross section of the tank. Tanks should have a length of 3 to 5 times their width, and a depth of from 6 to 10 feet. Inlet baffles or multiple inlets are required in tanks over 8 feet wide to promote uniform flow over the tank cross section. The effluent is withdrawn over an outlet weir after passing under a grease and scum baffle. Solid matter which settles to the bottom contains 92 to 98 percent moisture and is known as sludge. Sludge will undergo gradual decomposition due to bacterial action and will finally turn black in color and become inoffensive. During decomposition methane and other gases are produced and the sludge concentrates into about half its original volume.

If settling tanks are equipped with mechanical bottom scrapers, the sludge is removed daily and can be digested in *separate* sludge tanks. Mechanically cleaned settling tanks in large sewage plants usually provide about two hours detention at the average rate of flow. For smaller plants longer detention periods are used. Since mechanical equipment is difficult to obtain at advance bases, tanks in which the settling and digestion processes are combined must be used. Septic tanks and Imhoff tanks are examples of the latter type.

SEPTIC TANK

The septic tank (figure 42) is a plain settling

tank in which the sludge is permitted to accumulate and digest for relatively long periods. It is not an efficient device because digesting solids are raised by gas bubbles and pass out with the effluent. During rapid gasification, the effluent may contain more suspended matter than the influent. Ordinarily not more than 50 percent of the suspended matter and 25 percent of the biochemical oxygen demand are removed in a septic tank. The effluent is but slightly less contaminated with bacteria than the raw sewage. Septic tanks should provide 12 to 24 hours retention based on the average daily sewage flow plus an allowance of 3 cubic feet per person for sludge storage. Typical tank dimensions are given in the following table:

TYPICAL SEPTIC TANK DIMENSIONS

Basis of design. Settling period—12 hrs. for average flow. Sewage—50 gals. per capita daily. Sludge storage—3 cu. ft. per capita.

Persons Served	Width Ft.	Length Ft.	Depth * Ft.	Volume Cu. Ft.
100	6	18	6.0	630
200	8	24	6.6	1,260
500	10	36	8.8	3,150
1,000	Use two 500-person tanks			6,300

* Exclusive of freeboard.

Septic tanks are used to reduce the rate of clogging of soakage pits, sand filters and subsurface tile disposal fields, or to prevent the formation of sludge banks in small streams or bays. They are very useful for preliminary treatment of sewage but should never be considered as accomplishing alone a degree of purification that has much public health significance.

IMHOFF TANK

This is a two-story tank originated by Karl Imhoff but no longer restricted by patents. (See figure 43). Solids settling in the upper central compartment pass through slots to the lower part of the tank. The advantage in this arrangement is that settling solids are not returned to the flow by the gasification process. The settling or flow-through compartment should provide a 3-hour detention period based on average 24-hour rate of flow and the sludge compartment a volume equal to 3 cu. ft. per person served. Sludge volume is computed from a plane 18 inches below the slots. Gas wells should comprise at least 1/5th of the horizontal area of the tank, but may not be reduced to less than 2 feet in width. Results to be expected from the Imhoff tank are 40 to 70 percent removal of suspended matter and from 25 to 40 percent removal of biochemical oxygen demand. The following table gives typical tank dimensions.

TYPICAL IMHOFF TANK DIMENSIONS

Basis of design. Settling period—13 hrs. for average flow. Sewage—50 gals. per capita daily. Sludge storage—3 cu. ft. per capita.

Persons Served	Width of Settling Comp.-Ft.	Width of Gas Wells	Length Ft.	Depth * Settling Comp.-Ft.	Depth Below Slots Ft.	Settling	Volume Cu. Ft. Sludge
250	4	2.0	12	6.0	11.5	209	750
500	6	2.0	18	7.5	12.8	418	1,500
1,000	8	2.0	24	9.0	15.6	836	3,000

* Exclusive of freeboard.

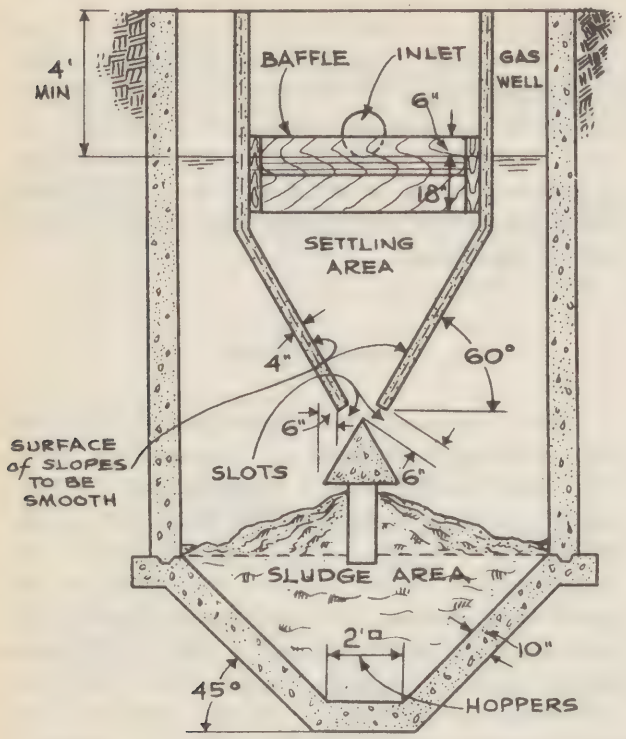


Figure 43.—Imhoff tank.

Operation of Settling Tanks.—Settling tanks must be given proper care if they are to function properly. Excessive amounts of grease should not be permitted to enter, and rainwater, surface drainage and liquid wastes which do not require treatment should be excluded from the sewerage system. Tanks should be inspected occasionally to check their operation and to determine depth of accumulated sludge and scum. When scum in the gas vent of an Imhoff tank reaches a depth of about 8 inches it should be broken up or removed and disposed of by burial. Sludge should be removed at least annually, preferably in the spring. Since the sludge from combined settling and digestion tanks may contain disease-producing bacteria, disposal should be by burial, dumping at sea, or fill in an isolated area. Drying on sand beds usually precedes disposal by one of the above methods. The effluents from the tanks discussed here contain large numbers of bacteria, so must be disposed of by dilution in a large body of water or by drainage into a disposal field or seepage pit, or must be given additional treatment.

Absorption.—Where the volume of liquid waste is small and the soil is sufficiently pervious, it may be possible to dispose of liquid wastes by absorption in the soil. Soakage pits and trenches described under Urine Soakage Pits and Trenches for use in disposing of urine may be used for disposal of water and showers, lavatories, laundry and galley. The volume of liquid waste and the absorptive character of the soil determine the size of the pit or trench required. A small test pit will furnish useful information on absorptive capacity of the soil. Subsurface tile fields or cesspools may also be used. These methods are not suitable if the water table is close to the ground surface for considerable periods during the year. Liquid waste containing an appreciable amount of suspended matter should not be disposed of into the soil until it has been given settling treatment.

Subsurface Disposal.—With this method waste liquid is conducted into the upper layers of the soil through a system of open joint tile or concrete pipe. (See figure 44). Since continued satisfactory operation depends on bacterial decomposition of organic matter, subsurface tile systems should not be more than 2 feet below the surface. At greater depth bacterial action is very slight. Main distribution or manifold sewers are laid with tight joints on a grade that will convey the sewage at a velocity of 2 feet per second. Laterals of 4 or 6 inch

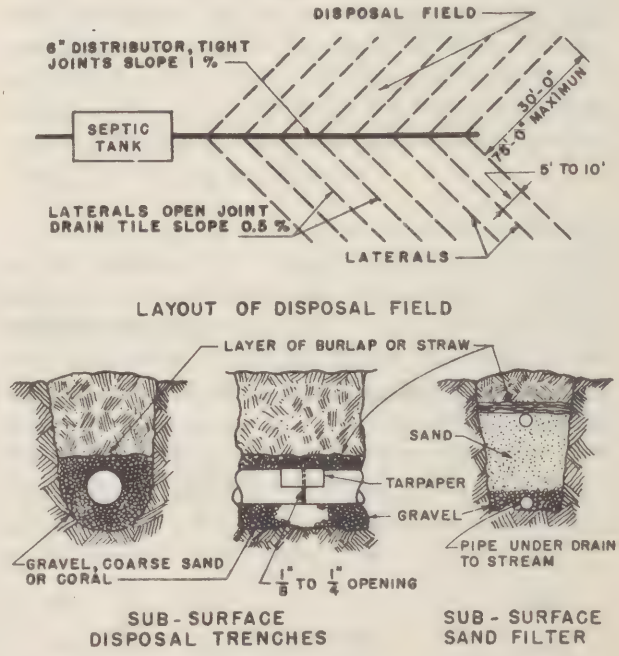


Figure 44.—Subsurface disposal systems.

drain pipe are laid on about a ½ percent slope with open joints, ⅛ to ¼ inch wide. The upper circumference of the joints are covered by strips of burlap or tar paper. Laterals are laid in trenches from 1 to 3 feet wide and spaced 5 to 10 feet apart, depending on the porosity of the soil, and from 1 to 2 feet deep, depending on surface contour and depth of soil. Laterals should be less than 100 feet in length. The tile is placed near the bottom of a bed of broken stone, gravel, or coral about 1 foot deep and the full width of the trench. The bed of stone is covered with straw, leaves or burlap and the trench backfilled. The laterals may be connected to the main distributor by Y-fittings. It is good practice to divide disposal fields into two sections so that each section can be rested at regular intervals.

Seepage Pits or Cesspools.—A seepage pit is a covered pit with open joint lining through which waste liquid may seep or leach into the surrounding porous soil. These pits may be used for disposal of liquid waste when the absorptive capacity of the soil is adequate. The pit is usually dug 5 feet or more in diameter and 6 to 10 feet deep. Sufficient wall area should be provided to permit liquid waste to leach into the soil without overflowing. The pit should be lined with stones, brick or concrete blocks laid dry up to the elevation of the inlet. Above the inlet the joints should be sealed with cement mortar. The distance between seepage pits should be more than 20 feet.

Absorption Rates.—The absorptive capacity of soil is estimated by digging test holes, filling them with water, and observing the time required for the water level to drop a given amount. The bottom of the test hole should be at the level of the absorptive area to be employed. If the test holes are made 1 foot square and filled with 6 inches of water, the absorption capacity may be estimated from the following table. Since dry soil will ordinarily absorb water more quickly than moist soil, the test should be continued long enough to saturate the soil around the test pit. If there is a protracted wet season during each year the tests should be made during this season or allowances made for conditions during the rainy season. Absorption should not be employed in soils of less capacity than the lowest in the table.

ABSORPTION RATES

Time for Water in Test Hole to Fall 1 Inch	Subsurface Disposal Trench: Estimated Absorption Capacity Per Sq. Ft. of Trench Bottom	Seepage Pit: Estimated Absorption Capacity Per Sq. Ft. of Percolating Area
1 minute	4.0 gal. per day	5.3 gal. per day
2 "	3.2 "	4.3 "
5 "	2.4 "	3.2 "
10 "	1.7 "	2.3 "
30 "	0.8 "	1.1 "
60 "	0.6 "	0.9 "

Subsurface Sand Filters.—When absorption is impossible because of tight impervious soils or a high water table, a subsurface sand filter can be used for disposal of liquid waste. An underdrain is placed in a trench or series of trenches and covered with a layer of gravel or crushed stone. Upon this is placed 12 to 18 inches of coarse sand. A second line of pipe is placed on the sand and covered with a layer of burlap or straw and the balance of the trench backfilled. The sand layer between the 2 lines of pipe serves as a filter medium. Liquid waste is applied through the upper system of pipes and the clear drainage is removed by the lower system and conveyed to a drainage channel.

Evaporation Beds.—Evaporation beds may be used where the soil is impervious and the climate is hot and very dry. These beds are made by scraping off sufficient top soil to level the area and then constructing an earthen dike 10 to 15 inches high. The leveled surface is then corrugated by raking the bed into a series of ridges. For kitchen waste, 3 square feet per person should be allowed. Two square feet per person is sufficient to care for bath waste. Beds should be arranged so that waste will be directed to all parts, and a sufficient number of beds should be provided so that some may be out of service for drying and respading. Kitchen wastes must pass through a grease trap before running onto the evaporation bed.

Dilution.—Disposal by dilution, i. e., the discharge of raw or treated waste liquid, into a body of natural water, is the only practical method of disposing of large quantities of sewage. Dissolved

oxygen in the diluting water is utilized through the activities of bacteria to stabilize organic substance in the liquid waste. If the receiving stream or body of water is overloaded with organic matter, all the available oxygen will be consumed, in which case fresh water life will disappear and the water will become septic and odorous. The following ratios of waste liquid to fresh water will insure a safe volume of oxygen in the stream, lake or other receiving body:

1 part raw sewage mixed with 100 parts of fresh water

1 part settled sewage mixed with 70 parts of fresh water

1 part filtered sewage mixed with 10 parts of fresh water.

Sewage should not be discharged without treatment when there are water intakes, bathing places or shellfish beds in the vicinity of the outfall. When health protection is involved because of the presence of such facilities complete treatment of waste liquids by sedimentation, filtration and disinfection with chlorine may be required.

The degree of treatment and the efficiency of a sewage plant is expressed in terms of suspended solids removal, removal of biochemical oxygen demand and the removal of bacteria. Suspended solids settle in the receiving stream, lake or bay and form sludge banks which create obnoxious conditions as they undergo anaerobic decomposition. Biochemical oxygen demand (B.O.D.), which is determined by measuring oxygen consumption in samples of sewage effluent or dilutions thereof incubated for 5 days at 20°C, is a measure of the oxygen which must be supplied to support aerobic stabilization of the organic matter in a sewage effluent.

Proper dispersion of waste liquids in the receiving stream is essential. If discharged to a river, the outlet should be placed so that the current will cause rapid dispersion. If a lake or the ocean is the point of discharge the outfall sewer should extend to deep water at a point where prevailing currents will not bring polluted water back to the shore.

Secondary or Complete Treatment Processes.— Subsurface tile disposal fields and seepage pits described above are simple secondary treatment devices suitable only for the disposal of relatively small volumes of sewage under favorable conditions of soil, topography, and climate. When secondary treatment, i. e., treatment in addition to sedimentation, must be given the sewage from more than a few hundred persons, one of the municipal type biological processes must be used and the treated sewage then disposed of by dilution. Three processes are important: (1) the trickling filter process, (2) the activated sludge process, and (3) sand filtration. The many variations both in the design and the operation of equipment utilizing one or the other of these processes can be appreciated only by study of the literature dealing with sewage treatment. All three processes are methods of concentrating in tanks or filters the natural aerobic biological processes which operate to purify and destroy waste material in streams and lakes. Their purpose is to reduce the pollution load imposed on the natural bodies of water into which sewage is discharged.

Trickling filters are beds of coarse stone 6 to 10 feet deep over which sewage is intermittently applied through spray nozzles or rotating distributor arms. As the sewage trickles down over the zoogoeal film growing on the stones, organic matter is removed. The accumulated organic slime normally breaks loose and is discharged from the bed twice annually. During this unloading period the filter effluent is highly charged with suspended solids which are removed in secondary settling tanks provided for the purpose. Standard trickling filters are dosed at rates of 2 to 4 million gallons per acre per day. High rate trickling filters that treat 15 to 30 million gallons per acre of filter per day have been developed in recent years. These filters, which involve a variety of patented schemes for recirculating effluent through the filter do not give as high a degree of treatment as the standard rate filter. The standard rate trickling filter is the simplest and most reliable of all devices for the secondary treatment of sewage. The over-all efficiency of sewage plants having a low rate trickling filter is 75 to 95 percent removal of biochemical oxygen demand, 70 to 90 percent removal of suspended solids and 90 to 95 percent removal of bacteria. Chlorination removes additional biochemical oxygen demand and kills many of the remaining bacteria.

The activated sludge process involves blowing of air into the sewage or otherwise aerating it for a period of 6 to 8 hours in the presence of biologically active sludge. The sludge is settled in final settling tanks and pumped back into the sewage entering the aeration tank. The sludge performs the same function as the zoogoeal film on the rocks of a trickling filter, that is, it feeds on the organic matter in the sewage. Since the sludge grows during aeration, an excess above the requirements for the process appears in the final tanks. This excess sludge is returned to the sewage ahead of the primary clarifiers and is removed in the preliminary sedimentation tank to be disposed of along with other primary sludge. The construction cost or first cost of an activated sludge plant is generally less than that of a trickling filter plant of equal capacity. The cost of operating an activated sludge plant is, however, much higher. The process requires expert control and at best the results are apt to be erratic. The crystal clear effluent produced when this process is operating well, often leads to a favorable impression of the process that can not be supported by its average performance. When operating properly an activated sludge plant will produce a somewhat better effluent than a slow rate trickling filter plant.

The intermittent sand filter is an underdrained sand bed onto which 100,000 gallons or less of raw sewage up to 1,000,000 gallons of completely treated sewage per acre per day is applied in 1 to 4 intermittent doses. The sewage is flooded onto the bed as rapidly as possible. Time is then allowed for the liquid to filter through the bed and for the bed to aerate and rest before the next dose is applied. Three or more filter beds are usually required to attain the proper schedule of rotation. The sand surface must be raked or harrowed as necessary to maintain reasonably rapid filter rates. When raking is no longer effective the upper layer of the sand must be removed. Intermittent sand filters produce a high degree of treatment. They may be improvised without difficulty using only tile or concrete sewer pipe if natural sand beds are conveniently located. The large area required and difficulties with odors are the principal disadvantages of this method of treatment.

Large sewage treatment plants have screens for removing coarse solids and may have grit chambers to remove sand and heavy suspended matter that might clog pipes or cause excessive wear of pumps and other equipment.

Chlorination of Sewage.—None of the so-called complete treatment processes will eliminate all the pathogenic organisms from sewage. It may, therefore, be necessary to disinfect the treated effluent in order to proetct bathing beaches, shellfish beds, or water supplies if these are near the sewer outfall. Disinfection of sewage should not be employed unless required by a Department of Public Health or needed to protect naval personnel who have occasion to swim or work in the water near the outfall. Chlorine or chlorine compounds are used to disinfect sewage. Chlorination of the partially or completely treated sewage may also be used during hot dry weather to delay or inhibit decomposition in the receiving stream until the sewage has been widely dispersed. Chlorine is sometimes used in treatment of plants to reduce odors or to control the behavior of biological devices.

Not less than 0.5 parts per million of residual chlorine after a 15 minute contact period is needed for effective disinfection. Doses required may be expected to be in the following ranges: septic tank effluent 10 to 25 ppm, Imhoff tank effluents 5 to 20 ppm and trickling filter effluents 3 to 15 ppm. Since the character of any sewage effluent is subject to wide variations, chlorine doses must be frequently adjusted if uniform results are to be obtained.

Sludge Disposal.—Sludge from the sedimentation tanks of a sewage plant may be disposed of in a variety of ways. In plants having mechanically cleaned settling tanks the sludge is usually subjected to anaerobic digestion in separate heated tanks prior to its ultimate disposal. During digestion methane gas is produced and the organic solids are changed into humus-like material. Sludge gas is similar to natural gas and may be used to heat digestion tanks, to operate gas engines or for general heating purposes. Sludge gas has a fuel value of around 700 B.T.U. per cubic foot and is produced at a rate of about 1 cubic foot per day per person contributing sewage. The digested sludge is dried on sand beds or on vacuum filters and is then dumped, used as a low grade fertilizer or burned. Undigested sludge may be buried or barged to sea.

Salvage of Sewage Products.—Clarified effluent from secondary treatment processes can be used to

irrigate lawns and landscaping but care should be exercised with waters of high chloride since grass and shrubs may be damaged by its use.

Sewage solids to be used as fertilizer must be digested and dried, or if undigested must be kiln-dried at temperatures which will destroy pathogenic organisms. Only sludges with a low grease content should be used as fertilizers or as soil conditioning agents. Ordinary digestion does not guarantee absence of all pathogenic organisms, consequently sludge should not be applied indiscriminately to areas where personnel train or exercise.

Refuse Disposal.—Refuse includes garbage and rubbish. Garbage is waste food or waste material incidental to the preparation of food. Waste material such as tin cans, glass, paper, boxes, ashes, sweepings, etc., is classed as rubbish and may be combustible or non-combustible. Refuse produced at advance bases amounts to 1.5 to 2.5 pounds per day per person, one-third of which is garbage. If garbage is not handled and disposed of in a sanitary manner it will create a nuisance and provide food or a breeding place for rats, flies and other insects which contribute to the spread of disease. Combustible rubbish can usually be disposed of by incineration. Non-combustible rubbish may be dumped if precautions are taken to prevent water accumulations in which mosquitoes will breed, but disposal by sanitary fill is preferred. Garbage may be disposed of by burial, by dumping at sea, or by sale or gift. Mixed garbage and non-combustible rubbish may be incinerated if climate permits. Mixed garbage and non-combustible refuse can be disposed of by dumping at sea or by the sanitary fill method.

REFUSE HANDLING

Collection.—In the military services refuse is sorted into garbage, combustible rubbish, and non-combustible rubbish by the use of separate receptacles so that each type of refuse may be disposed of by the most suitable method. Garbage should be stored for collection in standard galvanized iron cans with tight fitting lids. Rubbish is placed in similar cans or boxes conveniently located to encourage their use. Tin cans must be properly disposed of to eliminate possible sources of insect breeding. Garbage receptacles should be kept covered and should be collected regularly and frequently for transportation to the point of ultimate disposal or to a central transfer station. In order to minimize spilling during transportation the cans should not be filled to within 4 inches of the top.

Garbage Stand and Transfer Stations.—In semi-permanent camps garbage stands should be installed adjacent to the galleys. The best garbage stand consists of a concrete block enclosure filled with stone and earth and capped with a concrete slab. It should have a concrete apron around the base. The platform should be at truck floor level to facilitate transfer of cans from the stand to the truck. If concrete is not available, stands may be made of wood. The boards forming the platform should be laid at least 1 inch apart to prevent accumulation of organic matter in the cracks. Wooden stands should be movable in order to facilitate cleaning and oiling the ground beneath them. It is better to keep the stand clean and the cans covered with fly tight lids than to attempt screening. Inclosed and screened garbage stands are difficult to keep clean.

A transfer station is required where garbage and rubbish are picked up by the same truck and the cans must be sorted before being sent to separate disposal points. This station should consist of a truck-height platform similar to the garbage stand but with an area of 150 sq. ft. per 1,000 men.

Receptacles used for garbage should be cleaned at frequent intervals with hot water, soap, and stiff scrubbing brush. When steam is available this should be employed to sterilize the cans. Provision should be made for straightening cans and lids. The platform should be scrubbed daily with a stiff brush and hot soapy water, and the ground surrounding the stand should be sprayed with oil weekly.

BURIAL

Trench and Pit Method.—At small outlying activities and on the march or in bivouac, garbage may be buried in trenches or pits which are 3 or more feet in depth. Each day's accumulation of garbage must be thoroughly sprayed with oil or given one of the other fly control treatments recommended for latrine pits. When the trench or pit is filled to within 24 inches of the surface the garbage is given a final thorough spraying and covered with 24 inches of well packed dirt. Non-combustible wastes such as broken glassware, sweep-

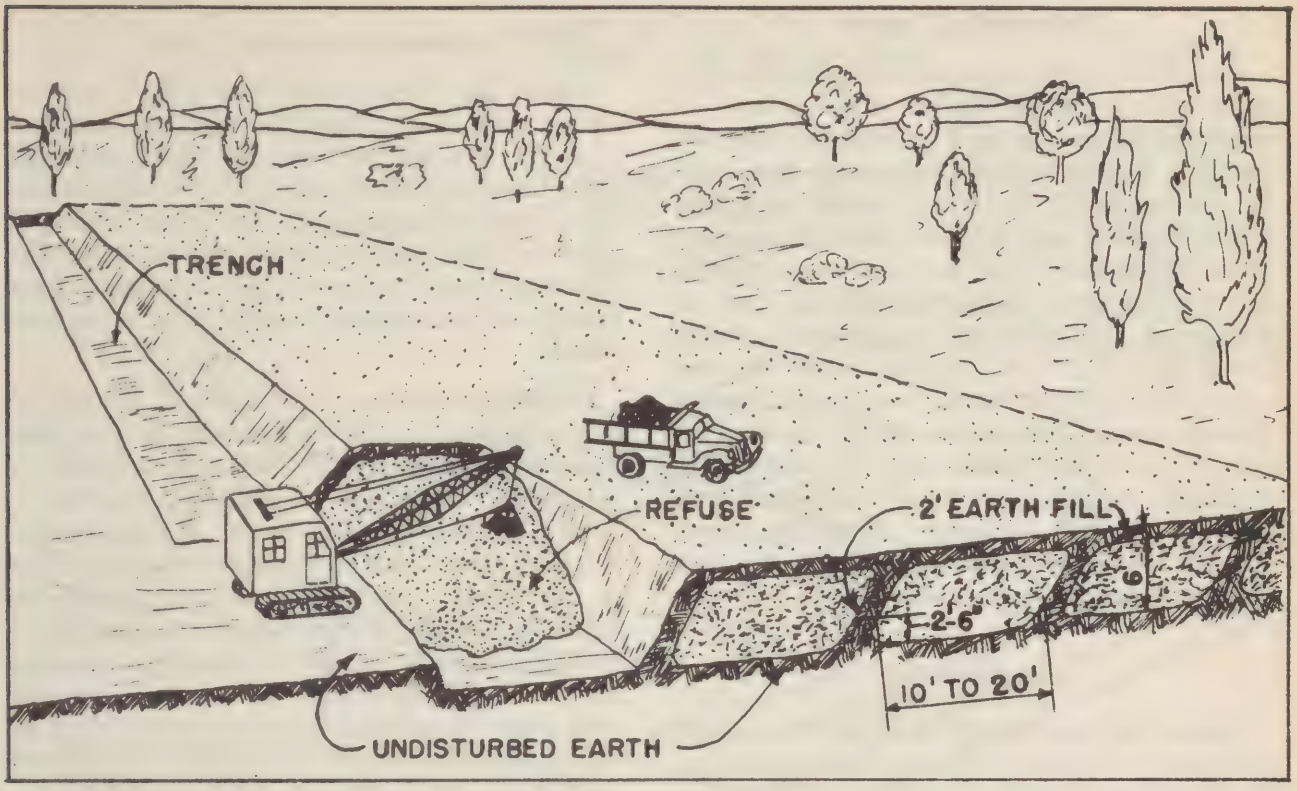


Figure 45.—Sanitary landfill.

ings, ashes and flattened tin cans can be disposed of on the surface without nuisance. At permanent or semi-permanent camps of considerable size, mixed garbage and rubbish may be disposed of by the sanitary landfill method.

Sanitary Landfill Method.—Low areas such as ravines, swamps and abandoned burrow pits are suitable sites for landfill, provided fill operations do not obstruct natural drainage courses. Earth, preferably sandy soil, should be available for cover material. Clay soil is not recommended as it does not provide proper sealing because of shrinkage.

Operation consists of dumping a mixture of garbage and rubbish in a layer approximately 6 feet thick, compacting it with heavy mechanized equipment, and covering it promptly with a layer of earth to exclude rodents and other vermin and to prevent the escape of odor or the outbreak of fire (figure 45). In the method illustrated, a trench about 30 inches deep and 8 to 24 feet wide is excavated to provide earth for covering the refuse already dumped. This trench is then filled with a 6-foot layer of refuse which is compacted by heavy mechanical equipment and promptly covered with 2 feet of earth from the next trench. At bases of less than 20,000 men, a *bull clam* shovel attached to a tractor may be used for digging the trench, compacting the fill and applying the earth seal. In larger camps, a power shovel or drag line may be used. Thorough compaction of the fill material assists in obtaining uniform settlement and reduces the amount of cover required. Although rats will ordinarily not burrow more than 12 inches, a cover of 24 inches in depth is necessary on the surface and face fills to compensate for uneven settlement. If flies have an opportunity to lay eggs in the garbage before it is covered with earth, the dumped material must be thoroughly sprayed with latrine oil or sodium arsenite solution before the earth cover is applied. An area of 0.75 to 1.5 acres will be required each year for each 10,000 men.

Most important factors for the success of this method are initial compaction of the refuse and cover, and maintenance of the completed fill. Maintenance involves trimming and filling cracks and eroded places. Inspection for the presence of burrowing animals should be carried out as needed.

DUMPING AT SEA

Disposal of garbage and rubbish by dumping at sea is sanitary and convenient. Often a study of winds and currents around an island or base will disclose a location where waste can be dumped at the shore or on reefs and will be carried completely and permanently away from the area. The dumping schedule frequently has to be timed to the tide for shore disposal to be successful. If disposal close off shore is not satisfactory the wastes may be barged 5 to 10 miles out to sea to a point where the wind and currents will not return them to the beaches. A barge must be assigned specifically for this purpose and a transfer station must be developed at the docks. Self-dumping barges improvised from pontoons facilitates discharge of the garbage at sea. Both the barges and the loading station at the dock must be maintained in a sanitary condition.

INCINERATION

Incineration may be used to dispose of a variety of materials with more or less success depending on the character of the waste, the type of incinerator, the climate, and the quality of operation and supervision. Combustible rubbish kept dry can be burned in the open or in the simplest of incinerators. Garbage or wastes from pail latrines can be burned satisfactorily only in enclosed or semi-enclosed incinerators provided with drying planes or platforms. Rubbish or other fuel must be used to fire an incinerator in which garbage is burned and continuous and careful charging and stoking is required. During seasons of heavy rainfall in the tropics incineration frequently fails. The characteristics of incinerators are as follows:

Closed type:

1. More quickly started.
2. Not so liable to be put out by rain.
3. Not so productive of bad odors.
4. Produces more heat.
5. Practical in permanent camps.

Open type:

1. More easily constructed.
2. Requires less material for construction.
3. Completely adequate for dry combustible rubbish.
4. Practical in semi-permanent camps.

Closed Type Incinerator.—The hillside and inclined plane incinerators are the most practical types for advance base use. In large permanent shore based activities a municipal type incinerator may sometimes be practical. The latter are complicated in design and would be selected only after consultation with engineers and equipment firms experienced in the construction of large incinerator plants.

Hillside Incinerator.—The "hillside" method of incineration (figure 46) first devised by Rear Admiral W. L. Mann, (MC), USN., and described in the journal of the *American Medical Association,* April 6, 1918, has proved simple and satisfactory. A trench about 2 feet wide, 3 feet deep and 6 feet or more long is excavated in a steep hillside or bank. At the foot of this trench a soakage pit is excavated and the bottom of trench and soakage pit are filled with stone. The trench is covered with sheets of corrugated iron or other metal to assist in creating a draft when the wood or rubbish fire is built over the soakage pit. Garbage or other waste is dumped at the top of the trench and is stoked gradually down the rock bottom of the trench. Liquids drain down into the rocks in the trench and pit where they soak into the ground or

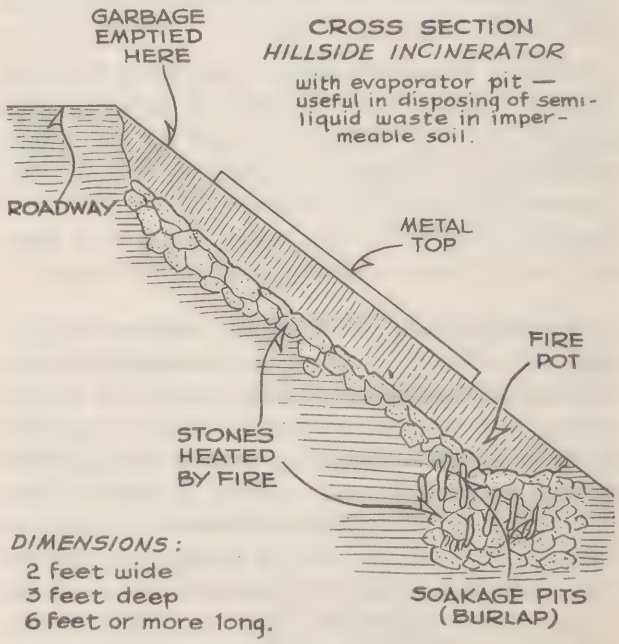


Figure 46.—Hillside incinerators.

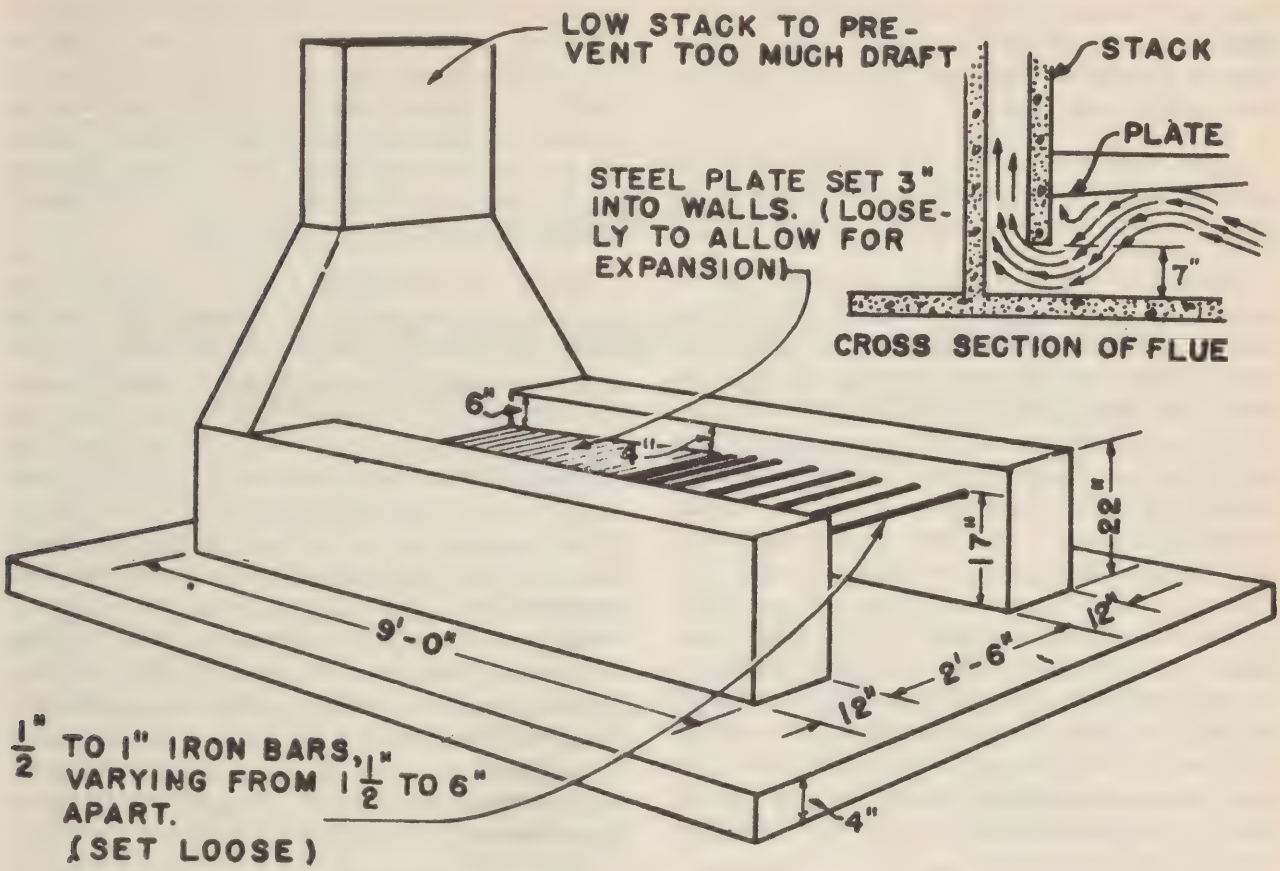


Figure 47.—Plate and grate incinerator.

are evaporated. The hot rocks and combustible gases dry the garbage as it progresses downward into the fire. This mode of disposal has the following advantages:

1. *Simplicity.*—One man can effectively and efficiently dispose of the excremental and garbage refuse of 5,000 persons.

2. *Availability.*—Almost every terrain contains a sloping hillside or a small embankment that may be utilized.

3. It requires a minimum of fuel.

4. A large surface area of liquid is exposed to heat thus facilitating evaporation. The hillside incinerator will prove most useful where there is a large mass of wet garbage to dispose of and where night soil must be burned.

Inclined Plane Incinerator.—This incinerator is a refinement of the hillside type in which the inclined drying plane is supported by walls. The incinerator may therefore be constructed on level ground. The walls and the floor under the grate are built of concrete, brick or rubble masonry. The inclined charging plane is either sheet steel, not lighter than No. 16 gage, or corrugated iron, or if the space between the walls is backfilled with local material the charging plane can be paved with stone. The incline is roofed over by means of pieces of oil drum, mounted in walls 8 inches or more above and parallel to the incline. Each piece of drum consists of one-third of a single drum, cut longitudinally clear through the ends. A fire of rubbish or wood is built upon the grate and after the incinerator has become hot, the garbage is shoveled or dumped from cans into the opposite, or upper end. The action of the hot gases will dry the garbage as it is pushed slowly down the incline. The ends of the oil drum sections serve as baffles and give rise to swirling of the hot gases, which greatly aids the drying out of the garbage on its

way to the grate where complete incineration is effected. Numerous varieties of this inclined plane type of incinerator have been improvised and used successfully in the field.

Open Type Incinerator.—Cross-trench, plate and grate and rock pile incinerators are examples of the open type which are suitable for field use.

Cross-trench Incinerators.—This consists of two intersecting trenches over which is placed a grate and the stack. The trenches are 12 to 18 inches wide, 10 feet long, and 18 inches deep at the grate or stack. The grate can be constructed of steel flats, 2 inches on centers, or may be made of any convenient pipe or metal rods. The stack can be constructed of stone or brick or improvised from an oil drum. During operation the leeward trenches are blocked with pieces of sheet metal to improve draft.

Plate and Grate Incinerators.—The incinerator shown in Figure 47 is large enough to dispose of the waste of 200 men. Wet garbage is deposited on the plate near the stack where it dries slowly. Portions which have dried sufficiently are raked over the iron rods where they are burned and fall into the fire box. This incinerator is fired with rubbish and scrap wood.

Operation of Incinerators.—Attendants should be trained to add garbage slowly to incinerators so that it will not put out the fire, to use care in dumping garbage receptacles so as not to injure the incinerator or the rectacles and to clean the firebox at frequent intervals to prevent burning the grates. The area surrounding the incinerator should be kept clean at all times. Ashes used as fill may have to be covered with earth to prevent their being spread about the camp by the wind.

Sale or Gift.—Garbage is often disposed of to civilians for hog food. This disposal may lead to insanitary conditions about a camp through spilling in transfer from garbage cans to other containers, leakage of containers, failure of collection, or unsatisfactory cleaning of cans. When thorough cooperation with the contractor can be maintained so as to insure cleanliness in the procedure, there is no objection to this method of disposal. However, the hog farm should be far enough removed from the camp that odors and flies will not be a nuisance. When garbage is used as food for hogs the edible garbage must be separated from the non-edible portion. The edible garbage from a 500 man galley will feed 10 to 15 hogs. It is recommended that garbage be cooked before being fed to hogs in order to reduce trichinosis. Garbage-fed hogs should be immunized against hog cholera.

NOTE: All of the illustrations and much of the written material contained in these notes were prepared by officers of the Bureau of Yards and Docks.

CHAPTER 6

BASIC DATA FOR MILITARY USAGE OF DDT, REPELLENTS, AND OTHER CHEMICALS FOR INSECT CONTROL

Since insect-borne diseases have been the cause of by far the largest proportion of non-effectiveness of personnel in many theaters of war, the development of chemicals for insect control has played a most important role in increasing and safeguarding military efficiency. Several chemicals are now available whose proper use may result in the saving of many of the casualties now charged to insect transmission. Since the application of these chemicals must be made correctly to achieve the desired results, the exact details of these procedures must be known. This section outlines some of the present known uses of insecticides for war areas.

ASSUMPTIONS

It is assumed for completeness that the target area involves the following insect hazards:

Biting gnats (phlebotomus fever)

Flies (dysentery and other diseases)

Mosquitoes (malaria, dengue and others)

Lice (typhus)

Mites (scrub typhus)

Fleas (plague and other diseases)

Ticks (tick-borne fevers)

Certain other insects not necessarily of prime medical importance.

DDT (Dichloro-diphenyl-trichloroethylene) is a complex organic chemical that was first synthesized by a German chemist in 1874. Until the Swiss, in 1939, reported it to be an effective insecticide, DDT was merely another *test tube* chemical. Not until November 1942 was DDT proved to be a most valuable insecticide for use by the Armed Forces. Since that time, an enormous amount of laboratory and field testing has shown DDT to be a rather general purpose insecticide. So important is this chemical that in less than two years large scale manufacturing processes were developed and it is now available by the hundreds of tons per month for use in military operations.

Because of the unusual toxicity of DDT and the radically different methods with which it should be applied, special knowledge and training is required if full advantage is to be taken of the potential savings in material and labor made possible by this chemical. These directions are intended to serve as a practical guide to the efficient, safe and economical use of DDT. They are primarily designed for use of personnel entering or about to enter areas where insect-borne diseases constitute a major military hazard.

A very serious danger in the use of DDT is the tendency to regard it as a cure-all that will remove all insect hazards with little effort. This is NOT the case. Men must still work at spraying, painting, or dusting DDT, and the men using it require more skill and training than ever before. Most dangerous is the tendency to neglect routine measures of sanitary disposal of human waste, garbage, and trash, with resultant failure to attain permanent sanitary control. The use of DDT should

augment, not replace, the older standard methods of sanitation.

PRECAUTIONS

Human Toxicity.—DDT is a toxic substance, but when the proper precautions are taken there will be no danger to personnel. At the rates of application recommended, DDT is not a health hazard. It is much less toxic than the arsenicals or sodium fluoride commonly used as insecticides. *The solutions in oil are readily absorbed through the skin and should therefore be handled with care. DDT* in dust is not absorbed through the skin and like the aerosol form is considered safe. DDT has been recommended for military use only after careful study by toxicologists.

Safety Factor.—As practical demonstrations of the safety with which DDT may be used, the following illustrations are cited: a group of Army enlisted men were exposed daily for over a year spraying mattresses in a barracks with a kerosene solution; several individuals doing research on many occasions, had large areas of their bodies covered with concentrated DDT-oil solutions; these same workers were exposed to DDT aerosols for over two years; and workers remained in dusty DDT atmospheres for prolonged periods in applying dusts in the mass treatments for body lice, especially in North Africa and Italy, and no symptoms of DDT-poisoning were noted even with examinations using special techniques to detect industrial poisoning.

Handling.—Oily solutions can be used with safety if they are not allowed to remain on large areas of skin, and repeated or prolonged contacts are avoided. It is advisable to rotate the crews who prepare mixtures of this chemical. Do not expose the hands in oil solutions, and do not use sprayers that leak and may soak the clothes or hands of the operator. If it is necessary to keep the hands in DDT solutions for long periods, rubber gloves must be worn.

Use Around Food.—Extra precautions in galleys, messhalls and food lockers should be taken in spite of the apparent safety in the use of DDT. Un-packaged foods and cooking utensils should be either covered or removed while this chemical is being sprayed or dusted. This precaution is not necessary for painting of screens. DDT is tasteless and resembles flour so it must not be stored near food supplies.

DDT Plus Repellents.—DDT should never be mixed with repellents for skin applications. The repellents are good solvents for DDT and can act as vehicles for carrying it through the skin. *The complete impregnation of clothing with both DDT and a repellent (double impregnation) is not recommended* as the long period of exposure while wearing double impregnated garments might permit absorption of toxic amounts of DDT. The following outline will serve as a guide for clothing treatments with DDT and dimethyl phthalate in typhus areas:

1. In areas where only mite typhus is expected, clothing should be well impregnated with dimethyl phthalate.

2. In areas where only louse typhus is expected, clothing should be well impregnated with DDT.

3. In areas where both mite and louse typhus is expected, the choice of two procedures may be followed depending upon which form of typhus is considered the most important in the area:

   a. Where *mite* typhus is of primary importance and *louse* typhus of secondary importance, dust the clothes with 10 percent DDT louse powder and apply dimethyl phthalate with the barrier method.
   b. Where *louse* typhus is of primary importance and *mite* typhus of secondary importance, impregnate the clothes with DDT and apply dimethyl phthalate with the barrier method.

Respirators.—Personnel applying dusts or sprays in buildings for long periods should wear respirators. This precaution may not be necessary in out-of-door applications if the mateirals are delivered to the leeward.

Lack of Risk to Livestock.—When the oil solutions are used at the rates recommended there is no danger to livestock or wildlife, but heavy dosages of the emulsion may kill fish. Dosages in the emulsion form higher than 1 part of DDT to 10-million parts of water may prove fatal to all fish life.

EFFECT ON INSECTS

Action on Adult Insects.—DDT is an unusual chemical as it kills insects both through ingestion

and by contact. The contact effect is obtained either by applying DDT directly on insects, or on surfaces where they will walk or rest. The latter is perhaps the most interesting use of DDT as toxic amounts are absorbed through the appendages and the body wall of insects. The precise manner in which DDT kills insects is not known. However, the reactions indicate injury to the nervous system. A short time after exposure, movements become poorly coordinated. Tremors and convulsions develop prior to death.

Repellent Action on Adult Insects.—DDT does not repel insects, but after obtaining a lethal dosage they become restless and attempt to escape, dying elsewhere. For this reason, dead insects may not be found unless trapped in treated areas. In experiments, nearly all insects captured as they attempted to escape from the treated areas died within 24 hours.

Action on Mosquito Larvae.—For the most part mosquito larvae drown. Their coordination is so affected that they cannot surface properly. Culicine larvae require heavier applications than anophelines. In sewage effluent, they require still heavier applications than in clear water. However, the dosages recommended for larviciding are several times larger than the minimal lethal dose, and should not be increased arbitrarily unless they have been tried and found inadequate.

Contact Kill, Influence of Droplet Size.—While any droplet size of DDT spray is certain to carry a lethal dose of DDT to insects if it strikes them, use of a coarse droplet type spray is something like killing foot soldiers with cannon balls; the same amount of steel dispersed in machine gun bullets would kill a greater number of the enemy. In airplane spraying where contact kill is desired, the finer particle sizes are better, as they remain suspended in the air longer and are carried into sheltered locations by the air turbulence created by the aircraft. Smokes have even better dispersion into sheltered places. Fogs, aerosols, and smokes produce far more efficient and certain contact with adult insects than coarser sprays *provided they are not blown out of the area too soon.*

Speed of Action of DDT.—DDT is slow in affecting insects, therefore observations to determine kill should not be made too soon after treatments are applied. The time will vary according to the types and dosage of application, species of insect and whether the insects are in the adult or larval stage. Furthermore, in making checks on control following the use of DDT, it is important to understand that insects may be incapacitated or *knocked down* some time before they are killed. This knockdown time is much slower than that obtained by the use of pyrethrum. However, the final kill is much more sure than with previously known insecticides and it is necessary that conclusions regarding effectiveness of the method of application not be formed as a result of checks made too soon.

The actual time required for death depends upon the amount of DDT contacting the insects; with small amounts the insects may be alive after several hours but will not survive. In general, if the insects show that they are affected (tremors and unusual nervousness) they seldom recover.

A check on the degree of control for cockroaches should be made two to three days after treatment; for mosquito larvae, after 24 hours; and for adult flies and mosquitoes, two to four hours after treatment or exposure, (Many will die even after this period).

PROPERTIES AND SOLVENTS

Effect of Temperature.—DDT is a white crystalline substance with a melting point of 107° to 108°C. It is stable under most conditions and does not deteriorate when exposed to sunlight or to temperatures such as are encountered on board ship or in the tropics.

Solubility.—This synthetic organic chemical is nearly insoluble in water, moderately soluble in petroleum and vegetable oils, and readily soluble in a number of organic solvents. *Concentrations greater than 5 percent should not be attempted in the field.* Kerosene and diesel oil will be the common solvents used. Although they may dissolve more than 5 percent, an attempt to use the higher concentrations greatly increases the difficulty in getting the material in solution and some DDT may precipitate out during cool weather. If a more refined material is desired for treating fabrics, such as bed nets, a 5 percent solution in Stoddard's solvent (a standard cleaning fluid) may be used. For fly spray a 1 percent concentration in purified kerosene may be used. Alcohol (ethyl) is a poor solvent. It should be pointed out that solvents,

especially different lots of the petroleum oils, will vary greatly in the amount of DDT that they will dissolve. Solubility increases with rise in temperature.

Use of Toxic Solvents.—Certain excellent solvents for DDT are readily available in the field; these are chiefly the chlorinated hydrocarbons. Due to the high toxicity to man, their use has been prohibited.

FORMS IN WHICH SUPPLIED

Three Main Forms Supplied.—The types of DDT furnished by Navy, Marine Corps, and Army are largely similar. DDT is supplied as: (1) the pure, or concentrate powder (coarse); (2) as 10-percent DDT (finely ground) in talc or pyrophyllite; and (3) in solution as an emulsion concentrate (25-percent DDT, 7-percent triton X-100, 68-percent xylene). The Army also provides a finished spray, 5 percent DDT in kerosene. Freon-aerosol bombs now being issued contain only pyrethrins.

Allowance Tables.—Allowance lists for DDT are published from time to time by type commanders.

Advantages and Disadvantages of Each Form.

1. *The pure concentrate powder is suitable only for dissolving in oils or organic solvents.* It is commercially pure DDT and much too coarse to be applied as a powder. It has some practical advantages in shipping, and offers the user a choice of solvents. It takes some time and trouble to prepare solutions. Inasmuch as all of the vehicle must be shipped in, usually in oil drums, there is ordinarily no saving in shipping space over a ready prepared solution.

2. The *10 percent dust* is ready to use, and can be applied rapidly. It is very effective as a residue where not disturbed and can be used as a larvicide. It is safe to use directly on the human body. The DDT dust is shipped in a higher concentration than is ordinarily used for larviciding or for use in dusters against adult insects, other than body lice, and usually no local diluent is available.

3. The *emulsion concentrate* is the most general purpose form in which DDT can be supplied. It requires less total shipping space than other forms because it can be diluted with water. It can be used as a larvicide, insecticidal spray, residue spray for buildings or vegetation, and for impregnation of clothing.

4. The *finished residue spray,* 5 percent in kerosene, requires a large amount of shipping space. However, it is ready for immediate use. Also, in areas where the kerosene used as a solvent is shipped as a separate item in barrel lots, it should be just as economical to ship the finished spray.

PREPARATION OF SOLUTIONS, EMULSIONS AND DUSTS

DDT can be used in many ways: In solutions, emulsions, aerosols, dusts, and smokes. *The amount of DDT applied per unit area is the important factor in the use of this chemical, and the amounts of diluents used are varied only to insure an even or easy distribution of the DDT.* The actual concentration used in practice will depend upon the equipment available in the operational area. Solutions in petroleum oils will be the most widely used in almost all theaters of operation.

Preparation of Oil Solutions.—The DDT dissolves rather slowly in oil, especially if lumpy, therefore solutions should be made up preferably several days before expected use. In order that DDT spray solutions will be available for immediate use on an assault beachhead several barrels of DDT in oil should be prepared, placed in five gallon expeditionary cans, labeled and placed on the ship in position for early unloading. If the material is very lumpy, it may be desirable to crush the lumps before adding oil. If the material is prepared in barrel lots, the DDT may be added to the oil in the barrel (after removing 5 or 6 gallons) and the drum either heated on a small fire and agitated; stirred with a rod inserted through the large opening in the drum; or the oil may be poured into an open barrel and stirred vigorously with a paddle. The DDT should go into solution in less than an hour if stirred constantly. A slower method is to add DDT to a drum of oil, leave it in the sun, rolling it occasionally. For large scale operations, mechanical mixers should be used. These will dissolve the DDT in 8 to 20 minutes depending upon the concentration, type of oil and efficiency of the mixer. Some control units have installed motor-driven paddles in barrels, and several are using air compressors to bubble air through the DDT-oil mixture. A windmill device with a paddle agitator would also save hand labor.

Weighing or Measuring DDT.—If scales are not available for routine use and the DDT is not in

containers of the proper weight for the solution, it will be necessary to calibrate a container and measure the DDT volumetrically. A #10 food can (approximately one gallon) two-thirds full, holds about two pounds of DDT, the actual weight depending upon the individual DDT sample. Due to the high toxicity of the insecticide, accuracy of concentration is not critical. *A solution sufficiently close to 5 percent for practical use may be prepared by adding two pounds of DDT to each five gallons of oil.* Twenty pounds to an oil drum short by 5 or 6 gallons of being full, is a useful proportion.

Varying Solubility in Oils.—Various oils, and various lots of the same oil differ in the maximum amount of DDT that will go into solution. *Concentrations higher than those recommended should not be attempted* or the DDT may crystallize out at low temperatures. It is suggested that when difficulties are encountered in getting the DDT into solution that a small sample be tested to determine if the oil will actually dissolve the amount of DDT necessary for the desired solutions. In some cases the oil may not dissolve the required amount and then it will be necessary to decrease the concentration.

Types of Oily Solutions:

1. A solution of DDT in Diesel oil #2 is commonly used for larviciding. It is undesirable for residual work indoors, and inferior to kerosene, indoors or out, for that purpose. Kerosene dries faster, makes finer crystals, catches less dust, and is less likely to be absorbed by the treated surfaces. *Lubricating oils* are not recommended. They have a viscosity too high for use in hand sprayers and they do not spread on all water surfaces sufficiently to make a coarse spray or a pouring method reliable.

2. *Kerosene* is well adapted for use in residue treatments in buildings or on cloth such as bed nets and mattresses. Purified kerosene is not recommended for residues or for larviciding as it will not dissolve enough DDT without the use of an auxiliary solvent. It will make a good base for 1 percent DDT to be used in hand fly sprayers (flit gun type).

3. *Diesel-lube oil mixtures* are used in airplane spraying. The lube oil is added to retard evaporation of the small droplets. The viscosity of the final mixture is the important thing. Tables of satisfactory mixtures will be found in a special bulletin of this series concerning airplane dispersal, now in preparation.

4. *Fortified oil solutions* will be recommended for certain limited uses when solvents are available. They have practical applications:

a. In spraying for adult insects from planes with 10 percent solutions;

b. For residue treatments with low delivery sprayers;

c. To take liquid DDT concentrate into combat zones. When used for this purpose, the concentrated solutions are diluted to desired strength with kerosene or diesel in the field.

Emulsion Concentrate.—The emulsion concentrate can be stored indefinitely IF the container is kept tightly closed. Any clean water, including rain, river, sea or brackish water may be employed in the preparation of the emulsion. On standing, after dilution with water, a creamy layer may form at the surface. This in no way affects its action, and only requires that the emulsion be thoroughly stirred before it is used. *Metal parts are subject to rust following the use of the emulsion and should be rinsed and oiled to prevent corrosion.* For larvicide or residue applications a 5-percent spray material can be prepared from the emulsion concentrate by adding one part of the concentrate to four parts of water. Ten percent emulsions can be made by adding 1.5 parts water. If the concentrate is available it may be used for the first few days ashore thus making unnecessary the time consuming preparation of oily solutions during the most critical period of the operation. For the impregnation of clothing, a 2-percent emulsion is made by adding 1 part of the concentrate to 11 parts of water. The concentrate should be thoroughly stirred in making the emulsions to insure a uniform mix.

Dusts.—Ten percent DDT specially ground in talc or pyrophyllite has been supplied for residual applications, larviciding, and for the control of lice and other insects such as cockroaches, ants and fleas. Its advantage is its great killing power as a residue, and fast easy application with a high safety factor. It is a safe form to use directly on the living body. Louse powder is made with pyrophyllite; larviciding powder with talc. Pyrophyllite adheres to dry surfaces better, talc is easier to manufacture, otherwise they are interchangeable. The

chief disadvantage of the present DDT dust *for larviciding* purposes is that it is shipped in 10-percent strength and therefore is in too high a concentration for most purposes. Usually no local diluents are available. A 2-percent DDT dust is the recommended concentration as a larvicide, for the sake of economy in the use of DDT. If diluents are available such as talc, soapstone, road dust, etc., the 10-percent powder may be diluted and remixed in a mechanical mixer. Lime and DDT are incompatible and should not be used together. In the absence of diluents adjust the duster for a low rate of application and use the dust undiluted. *The concentrated DDT (insecticide, DDT, powder, dissolving) must not be used in the field as a dust as the particle size is too large to be effectively spread.*

TYPES OF APPLICATION OF DDT

Types of Application.—There are three distinct ways of using DDT and TWO distinct rates of application of DDT that are used for the control of insects. The choice of dosages depends upon the length of time the treatment is expected to be effective. *The two dosages serve different objectives and should not be confused.*

1. *Immediate or Contact Kill:* Low dosages are applied with this use of DDT. Control depends on direct contact of the adult insects with the chemical in the form of sprays, aerosols, smokes or dusts. Such applications are designed to apply the insecticide rapidly and are not sufficiently large for long lasting effects. However, repeated applications may gradually build up a residue or deposit of DDT.

2. *Residual Application:* The amount of DDT used for residual applications is large, up to 100 times that used for contact kills and the treatments may be effective for many weeks. *Because of the heavy dosage, residue DDT should be applied directly on limited targets on which insects are apt to walk or rest.*

3. *Mosquito Larvicide:* Ordinarily mosquito larvicides are applied with light dosages to give immediate kill ("1" above). In only very restricted situations are the heavy or residual applications used.

EQUIPMENT FOR APPLICATION OF DDT

Difficulty of Achieving Economical Dosages.—In general the light applications used with DDT for larviciding is such a radical departure from previous applications that workers will have to be retrained and better equipment will have to be provided. The old habit of putting down a thick film of oil must be broken, or else DDT may as well be omitted, and plain oil used. Spray nozzles must be provided that will provide a much finer spray than heretofore used. A one or three quart continuous pressure insect sprayer of good design will apply light dosages. However, only with airplanes can complete coverage be obtained easily, using from one to two quarts per acre. With the best hand equipment, well trained men moving fast can hardly cover an acre with less than one gallon. Nevertheless, *workmen must be taught to get full coverage with the thinnest possible film of DDT.* Special hand equipment may be developed eventually that will facilitate these light applications.

Nozzles.—The primary objection to the present field equipment is the nozzle. To apply DDT insecticidal sprays properly, nozzles must deliver sprays of proper droplet size. The standard acceptable nozzle is equipped with a screen, whirlplate and spray disc. A disc opening, the size of a number 60-standard wire gauge (about 3/64 inch) will give a compromise droplet size for both residual and larvicidal application; 64-gauge disc opening would be better for larviciding. A disc size opening of 56 gauge would be better for residue work. Discs of wrong size aperture can be soldered or brazed and rebored.

1. *For Adult Killing and Larviciding:—A very fine fog type nozzle should be used ONLY for contact killing (killing of insects on the wing) or for larvicidal applications where a wind drift is desired.* In any sort of breeze or wind, fog will be blown off the target, and can not be used. The ideal droplet size is the smallest one that can be made to hit the target. Atomizing paint spray nozzles will give a fog-type of spray.

2. *For Residual Spray:*—For a *residue application,* a spray with a rather large droplet size is desired as the DDT should be applied to adhere on the surfaces where insects walk or rest and not "fogged" into the treated area with mist-type sprays. While the double-head nozzle with which the decontamination type spray is equipped is absolutely unsatisfactory for larvicidal spraying, its large droplet size is satisfactory for residual effect spraying. It does not deliver an even spray pattern

for residual treatments but it can be used if better equipment is not available. This nozzle is good for use in spraying sodium arsenite solutions. If a paint gun which gives a fog-type spray is used, it should be adjusted to give a large droplet size and the nozzle held close to the surface to be treated.

3. *Caution Against Removal of Screen and Whirlplate:*—All sprayers of the knapsack and cylinder type should be equipped with standard nozzles provided with screen, whirlplate and spray discs of suitable sizes for applying DDT solutions. *Under no circumstances should the screen and whirlplate be removed from the spray nozzle when applying DDT solutions* because the nozzle will then deliver a stream instead of a spray. Experience in the field indicates that a constant check will have to be made of spray nozzles. The men remove the whirlplate and enlarge the disc opening to make the sprayer deliver faster. It would be desirable to assign a numbered sprayer to each man to enforce these rules and to insure better care of the equipment.

Oil Resistant Fittings Needed.—Ordinary rubber washers, gaskets and hose deteriorate rapidly in contact with oils. This is a common cause of spilling DDT on the skin, by the leaking of valves, and clogging of nozzles with fragments of rubber hose. Rotting will be less rapid if the pressure is released when the apparatus is not in use. Oil resistant fittings should always be used in repairs, if not available as original equipment.

STANDARD PROCEDURES FOR CHEMICAL METHODS OF INSECT CONTROL DURING ASSAULT PHASES OF MILITARY OPERATIONS

1. *Measures Applicable to Military Forces.*—Newer methods which are specifically applicable to the problems of military forces during the most critical period af all, i.e., during the assault phases of ground operations are grouped according to those which should be initiated:

a. During the staging or pre-mounting period prior to proceeding to target area; and

b. Those applicable during the assault phases after arrival at the target area.

2. *Procedures To Be Undertaken During the Pre-mounting Phase:*

a. *Treatment of Bed Nets and Jungle Hammocks.*—Although the use of nets is limited during the early combat phases, they should be treated with DDT prior to departure to the combat area in preparation for the period in which they will be in general use. Such treatment kills mosquitoes attempting to rest inside nets; in addition, an appreciable total killing effect is obtained by their alighting on the outside of nets.

b. *Tents and prefabricated units,* such as huts and latrine boxes, to be installed early in the assault phase, should be given residual DDT applications in the staging areas. Such treatments may be expected to remain effective for several weeks or months depending upon the exposure conditions and will give aid in the control of insects until such time as routine treatments are established.

c. *Treatment of Clothing with Insect Repellents.*—Pre-treatment of clothing with repellent solutions during the mounting phase is of prime importance for protection against mites (scrub typhus). Against this type of insect the solutions actually are miticidal rather than repellent. The preferred repellent is dimethyl phthalate (DMP). DDT is not efficacious for this purpose.

Repellent treatment of clothing done primarily for mite protection affords considerable protection against fleas, ticks, and against mosquitoes, subject to the limitations noted below.

Value of treatment of clothing prior to mounting, for mosquito protection alone is limited due to the fact that the efficacy of the repellent will vary greatly according to the species of mosquitoes prevalent in any given locality. Furthermore, one thorough soaking with water removes enough of the repellent to make the treated clothing non-effective against mosquitoes. Pre-treatment with repellents therefore is usually not warranted for the sole purpose of mosquito protection. Smear, spray, barrier and immersion methods may be employed.

d. *Treatment of Clothing for Body Lice.*—DDT has made possible the effectual prevention of epidemics of louse-borne typhus. Two general methods are available: liquid impregnation, and 10-percent DDT powder applications. The impregnation method has the great advantage of protecting the individual without any special effort on his part and over a longer period than the dust method.

There are several methods available from which the most suitable procedures to meet the exact needs may be selected.

e. *Treatment of Gas Mask and Clothing Storage Bags.*—To prevent ants or other insects from resting and establishing colonies in gas mask bags, sea bags and foot lockers, such equipment should be either lightly dusted inside with 10-percent DDT dusts or lightly sprayed with 5-percent DDT in kerosene or in emulsion.

f. *Assembly of Equipment and Chemicals to be Carried to the Target.*—The efficacious use of DDT upon arrival at the target requires timely procurement, proper equipment, and chemicals in sufficient amounts.

DDT Solution.—In order to have DDT and other chemicals ready for immediate use upon arrival at the beachhead, stock solutions should be prepared in advance.

g. *Advance Indoctrination of Units in Measures for Individual Protection.*—Emphasis on the use of individual protective measures is a basic requirement. Men must know both the necessity for self-protection and the means by which they can afford themselves such protection. During periods of assault the two ounce bottle of repellent effective for mosquito and mite protection, the two ounce tin of DDT effective against lice, and the aerosol bomb to be used in tents and foxholes, may offer the only means of prevention of insect-borne diseases.

h. *Advance Designation and Training of Special DDT Teams to Carry On Measures for Group Protection.*—During the most active periods of assault, human excreta, garbage, dead bodies and other sources, allow enormous fly breeding to take place. Widespread dysentery follows almost inevitably. Another principle source of epidemics of disease are mosquitoes which transmit dengue and malaria. Previously it has seemingly been almost impossible to stop initial mosquito and fly-borne epidemics as the amount of man-power and equipment required could not be diverted from combat. The use of DDT immensely simplifies the task. A few trained teams can now prevent or markedly reduce the tremendous loss of man-days due to early insect-borne epidemics. Special provisions therefore should be made in advance for:

(1) The designation of, and technical training of insect-control teams.

(2) A specific prearranged plan of their activities upon arrival at the beachhead. Details of tasks to be undertaken are described in paragraphs to follow.

Procedures To Be Undertaken at the Beachhead During the Assault Phase.—Employment of the measures recommended in subsequent paragraphs will depend on several factors: the military situation, the care given to prior planning, and most of all, upon the ingenuity and initiative of those assigned the task of insect control. In general the plan contemplates:

1. Group protection by spraying of DDT from aircraft.

2. Group protection by insect control teams, covering the expanding beachhead as rapidly as the military situation will permit.

3. Individual protection, by each man using repellent and other individual protective measures where group protective procedures are not possible.

Group Protective Procedures to be Undertaken by Insect Control Teams.—There are two objectives: (1) control of flies; (2) control of mosquitoes.

(1) *Control of Flies During the Assault Phase.*—The extremely high populations of flies associated with combat operations usually appear about two weeks following the initial assault on the beachhead. Measures may be taken against both *larvae* and *adults.*

(2) *Fly Control by Larvicidal Action.*—Bodies may be treated by sodium arsenite solutions (penite), or by DDT in dust or spray form. Penite has proven very efficacious, its disadvantage being that arsenical toxic effect to individuals working with penite may occur unless great care is taken in handling. Special care should be taken to avoid contamination of water with penite. Whether DDT may eventually entirely replace arsenical sprays remains to be determined. A special technique of application of both chemicals is required.

Garbage and excreta, indiscriminately spread about the beachhead, should be subjected to the same treatment.

Straddle trench latrines and pit latrines, usually constructed later, should receive somewhat different treatment. Not only can penite and DDT sprays be utilized, but paradichlorobenzene (PDB) may be employed. Besides larvicidal methods, DDT residuals should be employed in and about latrines to kill adult flies.

Procedures Applicable To Front Line Troops.—Troops actively engaging the enemy and moving rapidly must depend largely upon repellents for protection. The individual issue may be applied to skin and clothing, or used to supplement prior impregnation of clothing. For *mite protection* DMP is preferred; for *mosquitoes,* the 6-2-2 combination is more effective. The use of repellents will also give a certain degree of *protection against fleas and ticks.*

Where *louse-borne diseases* are a hazard, the two ounce container of 10 percent DDT used by the individual, should supplement prior impregnation, as circumstances may require.

Front Line Troops Remaining in Stationary Combat for Several Days.—In such a circumstance every effort should be made to send up supplies of freon-aerosol bombs and 10-percent DDT powder. Killing of adult mosquitoes and reduction of fly densities can be accomplished both by dispersing these materials in the air and by the rapid killing effect of residues. Difficulties in moving such supplies to the front obviously require that the disease-transmitting insect population offers a sufficient hazard to warrant the procedure.

There is every indication, for instance, that if a team with rotary hand dusters would disperse 10 percent DDT powder in the immediate area where troops bed down in foxholes at night, that within a few hours a rapid, efficacious kill of adults could be expected.

Precision spot spraying by planes should follow the large scale treatments used during the beachhead operations. As the area becomes more stabilized spray should be applied to the localized breeding locations that are delimited by the entomologists.

Larvicidal teams would be useful in front lines only where the military situation might permit, and where the position of the troops was expected to remain stationary for longer than a week.

MILITARY ASPECTS CONCERNING THE USE OF AIRCRAFT FOR INSECT CONTROL

1. *Over-all Plan Adopted for Airplane Spraying of DDT.*—On the basis of aircraft and spraying equipment presently available, and what currently appears to be the best plan for DDT spraying, plans have been adopted to protect naval forces during both assault and garrison phases:

a. *Plan for Spraying During Assault Prior to the Capture of Airport Facilities Ashore.*—The urgent need for insect control at the earliest possible time has led to the adoption of a special plan for spraying by escort carrier aircraft. This operation is to be carried on only when insect problems in the assault area form a particularly serious disease hazard. Furthermore, it is planned only in those areas ashore which are occupied by our own forces and in which low level flying operations are considered reasonably safe. As soon as airport facilities ashore are established and are in readiness, DDT spraying operations by escort carrier aircraft will cease and will be taken over by land-based aircraft.

Assault phase spraying operations will be accomplished with combat aircraft, using specially devised spraying equipment.

b. *Aircraft Spraying Procedures During Assault Subsequent to the Establishment of Airport Facilities Ashore.*—Upon the cessation of escort carrier aircraft spraying operations, follow-up spraying procedures are to be carried on by land-based airplanes operating from captured or constructed airport facilities. F4U aircraft are to be used, with special apparatus designed for the two universal wing tanks which are ordinarily used to carry reserve supplies of gasoline. This apparatus will be assigned to fighter squadrons and may be quickly installed on the airplane for DDT spraying purposes, and quickly removed to enable the airplane to carry on a combat mission. In addition, airplanes spraying DDT can readily jettison their wing tanks while in the air in the event of combat necessity.

It will be noted that combat aircraft are used exclusively for assault spraying of DDT as combat situations require a fast and readily maneuverable airplane. Both the F4U and the TBM have a remarkably high load capacity, namely 300 gallons of DDT in solution. This amount is sufficient to cover

approximately a square mile of territory per single airplane mission.

c. *DDT Aircraft Spraying for Marine Divisions During Assault and Garrison Periods.*—Spraying by escort carrier aircraft or by land-based F4U aircraft from land-based facilities is to be made available to Marine divisions during combat. In addition small OY-1 aircraft may be assigned to Marine divisions to insure that aircraft capable of DDT dispersal will be continuously available. It may not always be feasible for Marine divisions to use these airplanes under combat conditions. However, they can be used for division protection during rehabilitation and garrison phases.

d. *DDT Spraying for Garrison (Non-Combatant) Phases.*—Two types of airplanes are appropriate for DDT spraying operations after assault. The first is a combat type of airplane, such as the F4U or TBM, equipped with the same apparatus used in assault. This type of airplane because of its large capacity meets the primary need of large area coverage. TBMs stripped of armor and other essential combat gear, with an added tank for greater capacity, may be assigned to certain bases for full-time DDT spraying.

The second type of airplane available to Navy forces for garrison spraying is the Stinson OY-1 (equivalent to the Army L-5, a small liaison airplane). Of relative low capacity (48 gallons of DDT solution) this airplane however is superior to the combatant aircraft in certain limited yet important aspects. These small airplanes can fly lower to the ground and over terrain which would be impossible or hazardous for the fast combatant aircraft, and they have the added advantage of being capable of spot precision spraying of small areas, thus permitting a much more thorough coverage with less waste of DDT solution.

It can be seen that each type of airplane has its advantages. One is superior for large area coverage; the other where thorough, small area control is desired.

ADVANTAGES AND LIMITATIONS OF AIRPLANE SPRAYING

Aircraft Spraying Versus Applications of DDT from the Ground.—So much enthusiasm has accompanied early trials employing aircraft for the dispersion of DDT that it seems well to emphasize along with its advantages, the inherent disadvantages and limitations of the procedure, particularly in its employment as a substitute for ground applications of DDT.

1. *Advantages of Airplane Spraying.*—It is at once evident that an enormous saving in labor and time is effected over that required for wide-area dispersal of DDT by ground crews. Furthermore, as demonstrated at Bougainville, airplanes will reach areas inaccessible to ground crews. They may be used during assault at times when ground crews cannot operate effectively. They may also be used safely over areas heavily mined. It is evident that airplane spraying of DDT can readily meet emergency situations where it is urgent that disease-bearing insects be brought under immediate control. This method permits a great saving of manpower at a time when labor either is urgently needed for other purposes or may not be available at all for insect control.

Another advantage of airplane spraying over ground methods is that if used properly, airplanes utilize one of the main advantages of DDT, i.e., that of effecting control by remarkably light surface applications of DDT solutions. Thus one of the common defects of ground application, which is over-dosage due to mechanical difficulty in dispersing sprays, is overcome by the airplane's ability to lay down a light and even dosage. This economy is lost when only small circumscribed, widely separated areas require treatment.

2. *Limitation of Airplane Spraying.*—Despite the above advantages, certain very definite limiting factors must be recognized in the employment of airplane spraying. The weather must be suitable for flying. Airplanes must be available and not diverted from primary combat tasks. Enemy action may effectively prevent airplane spraying procedures by making the operation too hazardous. Most important, spraying procedures may completely fail due to improper training and experience on the part of the pilot.

Another consideration is that in the use of DDT it has been demonstrated that specific and different types of applications are necessary for the effective control of various species of insects, and of adult insects as opposed to larval forms. The most effective application is usually easier to accomplish by ground methods as the airplane puts down only

one type of solution, and this solution may be totally inadequate or only partially effective. Furthermore, airplane application has little or no effect against insects hiding indoors or breeding under cover.

3. *Airplane Spraying of DDT Not a "Cure-all."*—From the above discussion it is evident that DDT spraying from aircraft is not a universally effective method which eliminates the need for all other methods for the prevention of insect-borne diseases. *Airplane spraying provides an additional control method possessing distinct military advantages, but rarely or never should be relied upon as a substitute for methods of insect control which are better carried out by ground crews.* The greatest advantage is gained by the most intelligent use of both ground and air methods.

DESCRIPTION OF SPRAYING APPARATUS FOR NAVY AIRPLANES

A large number of different devices have been developed for the spraying of DDT from aircraft. Three types of equipment which meet practical naval needs have currently been adopted on the basis of the most suitable available military aircraft, and on best performances in practical field trials in combat areas.

All three devices are capable of delivering with fairly even coverage two quarts of spray solution per acre, the equivalent of 0.2 pound DDT when 5% solutions are used or 0.4 pound DDT when 10% solutions are used. This dosage range at present is thought to be the most efficacious. The spray pattern is composed of a high percentage of droplets in the 5 to 200 micron size and a low percentage of droplets in the 200 to 800 micron size. The smaller droplet range appears to give the most satisfactory control. The tank capacity, area covered, and effective swath width vary with the type of aircraft:

1. *F4U (Corsair) Equipment.*—This apparatus, developed by ComAirPac, consists of two Mark V universal wing tanks, each equipped with an electrically driven fuel pump of 25-gallons per minute capacity (50-gallon total) and a delivery tube from the pump which ends in a baffle-type nozzle. The pumps are operated in parallel from a switch in the cockpit so that the flow may be turned on and off at the will of the pilot. This equipment may be mounted directly upon the drop tanks in about one-half hour with no alterations to tank or airplane. The tanks with equipment may be jettisoned in the air in emergency, and the airplane immediately employed in combat.

With slight modification, the universal wing tank with installed spraying apparatus may be used on other airplane types such as the F6F, PV and the Army P-38 and P-47.

The F4U has a capacity of 300 gallons (150 gallons for each of the wing tanks) and thus can treat 600 acres or approximately one square mile during a single flight. The swath width to obtain 2 quart acre dosage is 300 feet when ground speed is 165 m.p.h.

2. *TBM (Avenger) Equipment.*—This apparatus, also developed by ComAirPac, consists of a standard bomb bay auxiliary fuel tank with two electrically driven fuel pumps of 25-gallons per minute capacity each (50-gallon total), operating in parallel, and delivering through a "Y" connection to a single pipe leading out through the tunnel gun position. This apparatus may be installed in one-half to two hours without alteration to the airplane. An electric switch in the cockpit enables the pilot to control the flow at will. The spray nozzle is merely a small baffle at the end of the one-inch delivery pipe. The TBM has a capacity of 275 gallons and will treat 550 acres or, 0.86 square mile. The swath width to obtain 2 quart/acre dosage will be 40 feet with a ground speed of 70 m.p.h.

DDT Aircraft Spray Solutions.—DDT is usually dispersed from aircraft as either a 5% or 10% solution in oil. Several types of oil solutions have been widely used:

1. *Preparation of 5% Solution in Diesel Oil.*—A 5% DDT-Diesel oil solution is the most commonly used spray material. This solution is prepared by adding 20 pounds of DDT to 50 gallons of Diesel oil (either of the two usually available grades of Diesel, Cetane 45 or 50, may be used) and agitating with a mechanical stirrer or with compressed air until the DDT is dissolved. Agitation up to an hour or more may be necessary depending on the efficiency of the mixer, the condition (caking) of the DDT, and the type of solvent used. The 400 gallon decontamination sprayer with power agitator constitutes a good mixing tank.

2. *Preparation of 10% Solutions.*—It has been

the practice to use heavier concentrations of DDT, usually 10% solutions, if insect control problems are critical, as is usually the case during the initial phases of occupation. Some batches of Diesel, particularly cruder grades such as Cetane 45, will dissolve over 10% at subtropical temperatures. Using Cetane 45, 40 pounds of pure DDT concentrate powder may be added to 47 gallons of Diesel oil in a standard 55-gallon drum. After the addition of DDT, the solution will "bulk" to 50 gallons and will contain 0.8 lb. DDT per gallon or 0.2 lb. per quart (i.e., approximately 10% strength).

More highly refined Diesel such as Cetane 50 will dissolve up to 8% DDT (i.e., 32 pounds DDT per 48 gallons Cetane 50) at temperatures above 70 degrees Fahrenheit.

3. *Preparation of Solutions Using Special Solvents.*

a. *Velsicol Containing 20% DDT in Solution.*—While large amounts of this solution are available at the present time, final decision has not been made on whether this product will be routinely available. By adding equal parts of Diesel oil, a 10% solution is obtained. By adding three parts of Diesel to one of the Velsicol-DDT solution, a 5% solution is obtained. It is somewhat irritant and larger droplets burn vegetation resulting in possible agricultural loss.

b. *Trichloroethylene.* This material, a common grease solvent, is an excellent DDT solvent and is widely available in the field. At temperatures above 70 degrees Fahrenheit 50% strength solutions may be obtained by dissolving 4 lbs. of DDT in ⅔ gallon of trichlorethylene to make one gallon of solution. Below 70 degrees precipitation may occur but will redissolve readily on warming.

Trichlorethylene has the special purpose in the airplane-spray program of permitting a concentrated, (50% strength-weight/volume) solution to be placed aboard aircraft carriers. Diesel from the ships' own tanks is used for dilution, thus saving space and weight and eliminating the practical difficulties of dissolving DDT aboard ship.

Because of the toxic nature of trichlorethylene, (inhalation of fumes when in enclosed spaces), its use so far has not been considered warranted except aboard aircraft carriers. Details for the preparation and use of trichlorethylene concentrates for use aboard carriers are described in CinpacCinpoa Confidential Letter P-3, Serial 030853, dated 7 July 1945.

4. *Types of Solutions Not Recommended.*

a. *Kerosene* is not recommended as it often will not dissolve 5% DDT, and will evaporate too rapidly during spraying, giving an undesirable droplet pattern.

b. *Diesel Oil Plus Lubricating Oil.*—The spray solutions first recommended were Diesel oil containing various amounts of lubricating oil. The less volatile lube oil was added to retard evaporation of the smaller droplets, but this was subsequently determined to be unnecessary.

c. *DDT-Water Emulsion.*—Although the water emulsion has given satisfactory control of insects in field trials, it is not generally recommended because of its corrosive action on the spray equipment.

e. Better and safer solvents will eventually become available.

Cyclohexanone may be one of these.

STANDARD FLIGHT TECHNIQUE

The equipment provided for the F4U, TBM and OY-1 has been developed to deliver a swath of maximum width and droplets of general purpose size. It is designed to deliver two quarts of solution per acre when flights are made according to directions. The specified swath widths and speeds of flight should be followed whenever possible to insure the proper dosage of 0.2 pound of DDT per acre with 5% solutions or 0.4 pound of DDT per acre with the 10% solutions.

Speed of Airplane.—The OY-1 should be flown at approximately 70 miles per hour; the TBM and F4U at approximately 165 miles per hour.

Altitude of Airplane.—Aircraft should fly at as low an altitude as safety permits. If flown too high, the spray, especially the finer, more valuable droplets, will be blown away and will not fall on the area to be treated. The OY-1 will be most effective when flown 25 to 100 feet above the ground or ground obstructions; the optimum height for the TBM and F4U is 125 feet.

Spacing of Lines of Flight (Swath Widths).—

The effective swath, delivered by an airplane, is determined by measuring the width of distribution of the spray when the airplane is either flown into or with the wind. The swath width, which varies with different types of equipment, limits the distance between flight lines.

For the OY-1, flight lines should be 40 feet apart; for the TBM and F4U, 300 feet apart. If the flight lines are wider apart than specified, the dosage will be decreased and areas may be either untreated or too lightly treated.

Direction of Flight in Relation to Wind.—Ideally, flight lines should be made crosswind. In actual practice this may be impossible, especially with the fast-flying TBM or F4U. The object of flying crosswind is to take advantage of the wind drift which will aid in assuring good spray coverage, even when flight lines are flown inaccurately. When the flights are made directly into or with the wind, the swath is no wider than that characteristic of the equipment, but when flights are crosswind, the wind drift spreads the droplets so that a wider swath results. As the additional swaths are made, the droplets of various sizes overlap and give optimum coverage.

Pilots should observe the amount of wind drift, and adjust their lines of flight to insure complete coverage. If it is necessary to fly into or with the wind, the spray should be turned on and off at the proper time to allow for wind drift.

In actual practice, the most common error for inexperienced pilots is to "fly" the area to be treated and not to take into consideration that the emerging spray may drift into quite a different area. For instance, if the first swath is laid down on the windward or leeward side it may be necessary to start the first swath 300 or more feet from the edge of the area to be treated in order that the spray will strike the edge.

Wind velocities exceeding 15 miles per hour will greatly reduce the value of airplane spraying. Wind velocities up to 5 miles per hour aid greatly in good distribution, when flights can be made crosswind. As wind velocities are usually lowest in early morning and evening, it will generally be of advantage to schedule flights at those times. Best "inversion" conditions (i.e., best settling tendency) also occur from dusk to dawn.

Other Factors Affecting Spraying Operations.—The success of airplane spraying is largely dependent upon the pilot. The degree of effectiveness of this method of insect control depends upon the accuracy of his flight lines, and the accuracy of his allowance for wind drift. Therefore, it is important that the pilot be trained for this type of flying just as he would be for any other type of specialized flying. Since it requires experience to apply insect control sprays properly by air, pilots assigned to the program should not be continuously rotated.

1. *Training of Pilots.*—The most important part of the training of a pilot is to take him into the field so that he may become familiar with the problem from the ground. It would also be helpful if the pilot could assist on the ground in the training of pilots. Until the pilot can fly the swath lines accurately and make correct allowance for wind drift he should be guided by ground crews. Men should be placed at each end of the area to be treated to mark with flags each flight line and to guide the pilot in correcting for wind drift.

2. *Control of the Operation from the Ground.*—At least during the training period, it would be desirable to have two-way radio communication. Portable, ground-plane two-way radios make it possible to assist the pilot in making the proper corrections in his flights. In the absence of radio equipment, ground to plane visual signals must be arranged.

3. *Control of the Operation by Aerial Observation.*—Though it has not been used, aerial observation of spraying operations from a liaison type of plane would offer marked advantages when long flights are made. Plane to plane radio would be used.

4. *Formation Flying.*—Formation flying would appear to be safer, quicker and more effective than single plane flying, when large areas are to be covered.

PRELIMINARY TESTING TO DETERMINE SPRAY CHARACTERISTICS

Calibration and Observation of Spray Patterns.—Although the spray apparatus used on the OY-1, the TBM, and the F4U, has been designed to give certain swath widths and to deliver sprays at a

given rate and droplet size, it is important to check the actual field performance of equipment, especially when used for the first time.

1. *Delivery Rate.*—The rate of delivery can be computed by filling the tanks and determining how many minutes are necessary to empty the tanks during flight.

2. *Determination of Swath Width and Droplet Size.*—Swath width and droplet size can be measured simultaneously by using smoked slides.

a. *Preparation of Slides.*—For preparing smoked slides, ordinary microscope slides with a film of carbon deposited on one side can be used. The carbon film is applied by holding the slide over the flame of an ordinary kerosene lantern, smoking the slides uniformly to a density that will just allow reading newsprint through the film. The slides should be numbered, and placed in a slide box to prevent damaging the carbon film.

b. *Swath Width.*—In determining the swath width the slides should be placed on the ground, smoked side up and in a straight line *at right angles to the wind direction.* They should be spaced about 20 feet apart and over a distance of 400 to 500 feet. Reliable tests can be made only when there *is no breeze or when the breeze is very slight.* One flight should be made over the slides with the spray equipment in operation. This flight should be made at the altitude and speed specified for the particular spray equipment being tested and should be directly over the center of the line of slides and directly into the wind. It will be noted that enough slides are laid out over a wide enough area so that if the flight of the plane is a little off center or the wind drives the spray to right or left the swath width may still be obtained. Care should be taken to start spraying at least a half of a mile before reaching the line of slides and to continue for at least that distance after passing the slides. The slides should not be disturbed for at least 30 minutes, otherwise the smaller droplets which fall more slowly may be missed.

The spots on the slides, where the oil droplets strike the carbon layer, are easily counted under a dissecting microscope.

Count the droplets on a measured inch in the center of each slide. In examining all slides, if the experiment has been properly done, it will be found that the series of slides in the center have high droplet counts. Those laterally placed will have relatively low counts or no droplets at all. The effective swath width, which is the width used to determine the distance between flight lines for actually spraying purposes, is that distance covered by the slides with high droplet counts.

c. *Determination of Droplet Size.*—Droplet size measurements may be made at the same time and by using the same procedure described above for determining swath width. With a compound microscope, provided with a calibrated eyepiece, measure the spots on the slides where the oil droplets strike the carbon layer. When the droplet strikes the slide a circular spot results around which is a dark ring that is almost the same diameter as the droplet. Around each of these circular spots will be a halo-circle of larger diameter which is the area of the carbon film that has absorbed the oil droplet. To determine the diameter of the droplet, the diameter of the dark ring that surrounds the center circular spot should be measured.

Smoked slides will not provide an accurate count of droplets in the aerosol range.

IMPORTANCE OF SPRAY CHARACTERISTICS

Desired Performance as Regards Delivery Rate and Swath Width.—By carrying on the above tests, certain practical information is gained. The check upon delivery rate is necessary to assure that 2 quarts per acre will be applied at the ground speed and flight interval used. The observed swath determines the width of flight intervals which will give uniform coverage.

Desired Performance as Regards Droplet Size.—There is, at present, considerable controversy over the proper droplet size for aircraft sprays. Some equipment has been designed to deliver almost all the spray material in a rather uniform droplet size of less than 20 microns. Other equipment delivers relatively few droplets in this size range, most of the droplets being above 200 microns in size. The third type of equipment delivers a large percentage of droplets in the size range of 5 to 100 microns and few in the larger sizes of 100 to 400 microns. It is likely that the latter type which contains a wide range of small and large droplets will be

found to be a more general purpose spray. Definite conclusions have not been reached as to what droplet size is most efficacious. From both theoretical and practical standpoints, large and small droplet sizes each have distinct advantages and disadvantages. It is expected that spraying in the future will be accomplished with equipment which will lay down fairly uniform droplets, of a size which may be varied at will. The present apparatus lays down a spray with a very wide range in droplet size. Practical experience shows that the use of the wide size range which has been adopted gives the best results under a variety of conditions. In using an all-purpose spray, it is nevertheless important to bear in mind certain of the characteristics which will be exhibited by the smaller droplets as contrasted to those of the larger droplets.

1. *Effect of Meteorological Factors on Large and Small Droplets:*

a. *Effect of Wind.*—Large droplets, 400 to 800 microns in size, fall rapidly and are less affected by wind drift. They will tend to fall directly under the plane, while the small droplets, 5 to 10 microns in size, will drift considerable distances in a wind. If aircraft sprays must be used in areas where there is wind, it is necessary that sprays contain large droplets. Conversely, if the areas to be treated have little or no wind, the small droplets will not be blown away and will fall on the target.

b. *Effect of Convection Currents.*—In areas where there are strong heat convection currents the smaller droplets may not reach the ground at all, whereas the larger ones will not be greatly affected by these rising currents.

2. *Effect of Droplet Size on the Distribution of Sprays:*

a. *Effect on Swath Width.*—If the spray is composed of large droplets it is little affected by the turbulence created by the airplane and tends to fall directly down from the spray nozzles, resulting in a narrow swath. Small droplets are spread by the turbulence of the plane. This results in a swath as wide as the turbulence pattern of each particular airplane.

b. *Effect on Distribution Pattern.*—A given volume of spray liquid will break up into many more small droplets than large ones. For instance, one 400-micron droplet will make 64,000 10-micron droplets. A large number of small droplets falling on a unit area will more completely cover the area, and will give far greater opportunity for contact with adult insects than if a few large droplets fell on the same unit area.

c. *Effect on the Ability of a Spray to Reach Protected Areas.*—Since large droplets are little affected by air movement they will tend to fall straight down and will be screened out by vegetation or other objects covering an area to be treated. On the other hand, small droplets are not only swirled by the turbulence of the plane but are also subject to the air currents around such objects as plants and houses. Because they are moved laterally by such air movement, the small droplets are more apt to fall on areas protected by an overhanging cover.

3. *Effect of Droplet Size on Insect Control.*

a. *Desired Droplet Size for Mosquito Larviciding.*—Larger droplets can be used for the control of mosquito larvae than for adult insect control. This is because the oil droplets spread over the water surface, making unnecessary the complete covering of a surface with droplets. Smaller droplets are more desirable for larviciding as the surface of water frequently is covered with a film that prevents the spread of oil. Smaller droplets are also desirable as they will better reach protected water surfaces.

b. *Desired Droplet Size for Adult Insect Control.*—Smaller droplets, 10 to 100 microns, are much more useful for adult insect control. The smaller droplets remain suspended in the air for a longer time and may be thousands of times as numerous and thus have more opportunity to contact the insects than if the droplets are large and fall rapidly. A single droplet, 10-15 microns in size is lethal for either flies or mosquitoes. The residual effect of sprays as applied by air-sprays is still undetermined, but in many instances some residual effect is noted. If it proves practical to apply residues by air, it might be possible to use a larger droplet size than for contact kills.

TECHNIQUE FOR ESTABLISHING A SOUND BASIS FOR SPRAYING PROCEDURES IN VERY EARLY ASSAULT PERIOD

Spraying in Early Assault on an Empirical Basis.—The initiation of airplane spraying procedures as

early as D-Day may require that the operation be started before any real knowledge is at hand regarding the exact insect problems which are actually confronting troops. Under such conditions the principle is to spray only those areas occupied by troops with the intent of killing off any adult insect population which may be capable of disease transmission. The greatest value, as observed in past operations, will be in a kill of adult mosquitoes and flies. As a result of killing infected mosquitoes, the transmission of malaria, dengue, filariasis or other mosquito-borne disease will be immediately lessened; with the killing of the adult fly population dysentery, an inevitable accompaniment of every assault landing, may be very markedly reduced. Spraying for adults under these conditions will usually serve also to kill many mosquito larvae which may be present in sprayed areas but this objective will be of secondary importance. Fly breeding must be controlled by ground methods; without ground control of fly breeding the airplane adult kill program produces only the most transient results.

Strength of Solution:—On a theoretical basis alone, double strength solutions, (i.e., 10%) have been used for adult kills very early in assault. Further trials may prove that the 5% solutions are sufficient, though as seen below, one of the principal dysentery transmitters, the green bottle fly, Chrysomyia, seems resistant to low dosages of the less concentrated solution.

TECHNIQUE IN LATER ASSAULT AND THROUGHOUT GARRISON PHASE

Inauguration of Airplane Spraying on a Scientific Basis.—A shift from empirical procedure to a scientific spraying program should be made as early in combat as possible. For this purpose, the following steps should be taken:

1. *Entomological Survey to Direct Attention at Most Urgent Problems.*—Insect surveys should be made: (1) to determine the species of insects present, and to ascertain their densities; (2) to single out those species which are apt to be disease transmitters as opposed to species which are merely pests; and (3) to locate main sources of larval breeding and adult resting places of the medically important species.

The above survey will permit a direct attack on the most immediately dangerous insects, delimit areas where these insects occur, and determine what priorities should be established in the over-all control program.

2. *Decision Regarding Capabilities of Airplane Spraying.*—Having established the nature of the control problem by entomological survey, the next step is to determine to what extent the airplane may be efficiently used in the over-all program control. A decision in this regard requires (1) an understanding of the mechanism by which airplane sprays control insects, and (2) a knowledge of what actual experience has demonstrated that aircraft spraying can do.

Mechanism by Which Airplane Sprays Control Insects.—Too little precise information is available for a thorough understanding of the exact mechanism by which airplane sprays reduce insect population, especially as regards control of adult insects. Basically, DDT sprays have three modes of action: (1) larval kill, (2) adult kill by contact, and (3) adult kill by residual action.

1. *Larval Kill.*—The principal use of the airplane in insect control programs has been the control of anopheline larvae. Results have been good in all breeding situations, and with various types of equipment delivering various droplet sizes. Against culicine larvae, or the larvae of other insects, results have varied so much with the individual species, or with the various special breeding conditions, that no generalizations on the effectiveness of the air-method can be made.

2. *Adult Kill by Contact.*—A number of trials have demonstrated that airplane sprays reduce adult insect populations by direct kill. In general, the best results have been reported from test areas where the vegetation was high and dense, where there was little wind, and where the equipment used delivered a large number of small droplets (5 to 25 microns in diameter). The effectiveness in such instances appears to be due to the DDT aerosols remaining suspended in the air for prolonged periods. The kill with suspended aerosols is direct contact with flying or resting insects.

3. *Adult Kill by Residual Action.*—The degree to which airplane sprays control insects by DDT residuals is an extremely controversial subject. Trials frequently show the greatest reduction in adult insect population 24 to 48 hours after spray-

ing, and this reduction may continue over a period of several days to a week or more. Undoubtedly, such reductions are due to a residual type of action by DDT. On the other hand, other trials have shown no such reductions for reasons not at all clearly defined. Additional trials are necessary to show more clearly the exact role of airplane residuals in adult control.

CAPABILITIES OF AIRCRAFT SPRAYING AS JUDGED BY PAST EXPERIENCE

A general picture of the relative efficacy of DDT-air applications against various forms and types of insects is shown in Table 1:

TABLE 1

RELATIVE EFFECTIVENESS OF DDT APPLIED BY AIR FOR INSECT CONTROL

Degree of control is shown in *'s (—) equals no control

Type of Insect	Adults	Larvae
MOSQUITOES		
Anopheles	* to ***	****
Aedes		
Small container, clear water breeders (A. aegypti)	* to ***	Unknown
Open, clear water breeders (A. taeniorhynchus)	* to ***	***
Culex		
Clear water breeders	* to ***	***
Contaminated (organic) water	* to ***	*
FLIES		
Houseflies (Musca)	***	(—)
Bluebottle flies (Chrysomyia)	*	(—)
Sandflies	*	(—)
FLEAS	Unknown	Unknown
MITES	(—)	(—)

1. *Results of Airplane Sprays Against Mosquitoes.*—To date, the airplane spray has been more widely used against mosquitoes and has been found to be more useful against them than any other of the insects of medical importance. The DDT-air application is effective in various degrees, against both larvae and adults, but not against pupae or eggs.

a. *Mosquito Larvae.*—The airplane DDT-sprays have been used with complete success against *anopheline* larvae when applied at the rate of 0.2 pound per acre. In no area has the vegetation been too dense to prevent control of anophelines even with this light dosage.

Experience is adequate, at present, to generalize only on the effectiveness of air applications for the control of such culicine species as *Aedes aegypti* or *Aedes albopictus* whose larvae breed in small water containers such as cans, jars and tree holes. Judging entirely from their habits and their susceptibility to DDT, it is likely that the larval forms would be reduced, but not adequately controlled by airplane-delivered sprays. Sprays containing high percentages of small droplets would be more apt to disperse widely and reach the protected breeding locations of these species, and therefore should give a more effective control than sprays containing large droplets. *Aedes* species that breed in open water of marshes, such as *Aedes taeniorhynchus,* are more readily reached by larger droplets and good control can be expected from their use.

The effectiveness of DDT applied by air to control culicines varies with different types of breeding water. On Okinawa, DDT-air applications were not satisfactory against all culicines. Those that bred in contaminated water (water containing large amounts of decomposing organic matter) were not adequately controlled with dosages that were effective against clear water breeders. This is similar to observations made in the States in which five times greater dosage was required to kill larvae in sewage effluent than larvae in clear water.

Apparently there is also, for some unknown reason, species variation in susceptibility to DDT. The nature and extent of such variations has not been well studied. As an example, one study has shown that when a mixed population of *Culex quinquefasciatus* and *Aedes aegypti* larvae is treated with a light application of DDT, some *Culex quinquefasciatus* larvae will remain alive after all *Aedes aegypti* are killed.

The above experiences may be *summarized* by reducing to general principles that which practical experience seems to indicate to be correct at present:

(a) Aircraft spraying is of marked effectiveness against larvae breeding in waters of large surface area (even when surface plant life or debris is abundant and the forest overhead coverage is dense).

(b) It is relatively ineffective against species breeding in containers as many of the breeding places are inaccessible and can be reached only by fine aerosol sprays, and by these only when meteorological conditions are favorable.

(c) Organically contaminated water appears to have a property which renders DDT less effective.

(d) Species differences exist in larval susceptibility to DDT. These can be determined at present only by trial and error methods, but all species of anopheles larvae appear to be very much more susceptible than any culicine species.

1. *Adult Mosquitoes.*—Different workers have reported everything from poor to excellent control of adult mosquitoes by air application. Some claim that all the control resulted from direct contact, whereas others claim that the control was due to both contact and residual action. Tests against *Anopheles* and *Mansonia* in Panama, against *Anopheles* in Guadalcanal, and against *Aedes* both in the United States and in Alaska seem to indicate that airplane equipment, designed to deliver a high percentage of the total volume of spray in small droplet sizes (5 to 100 microns in diameter) will give up to 90 percent reduction of adult mosquitoes. Furthermore, some of these tests indicate residual action from such sprays lasting up to a week. Practical large scale field trials, under various conditions, are necessary before the exact role of the airplane for the control of adult mosquitoes can be determined.

Following larvicidal operations, there is frequently sufficient DDT on the water or vegetation to kill large numbers of adult mosquitoes as they emerge from the pupal skins.

2. *Results of Airplane Sprays Against Flies.*—Within the past year, airplane-DDT sprays have been used against flies in several military operations, usually with excellent results. The sprays are effective against adults, but ineffective against larvae, pupae or eggs.

On Peleliu it was estimated on the basis of a single test that an application of 0.2 pound of DDT per acre delivered by a TBM did not materially reduce the fly population (*Chrysomyia megacephala*), but that 0.4 to 0.6 pound of DDT per acre caused a reduction of about 70%. On Okinawa, 0.2 or 0.4 pound of DDT per acre not only caused a kill of nearly 100% in the case of houseflies (*Musca*) in a village, but the population remained low for at least a week. Similar applications did not noticeably reduce *Chrysomyia* populations except directly under the plane.

Certainly the airplane sprays are sufficiently effective that they can be used to aid in reducing dangerously high adult fly populations.

3. *Results of Airplane Sprays Against Other Insects.*—The use of DDT to control such pests as sandflies, fleas, mites and ticks has not been investigated sufficiently to know what place the airplane may have in their control. Air applications are reasonably effective against sandfly adults, but field tests to date indicate little or no effectiveness against larval sandflies, or against fleas, mites and ticks.

Pre- and Post-treatment Surveys and Observations During Spraying Operations.—The above discussion has shown the general capabilities of spraying by aircraft and the existence of many factors which may intervene to render airplane applications ineffective. With so little knowledge regarding the exact mechanism of these disturbing factors it is important that operations designed to control insects be routinely evaluated by careful surveys both before and after airplane applications. It is well in the post-survey checks to remember that residual effects may not become apparent until some time after the operation has been completed.

In evaluating survey checks it will also be found important to have data obtained by direct observation of spraying procedures. Frequently failures have resulted from poor flying technique or adverse meteorological conditions of which the pilot may have been quite unaware. The value of pre- and post-survey checks in guiding future operations depends on full and accurate data concerning every phase of each spray operation.

Spray Equipment for Ground Crews.

1. *Knapsack Sprayers and Cylinder Type.*—Sprayers, knapsack and cylinder types, all develop pressure adequate for dispersing DDT. The knapsack sprayer tends to spill oil on the skin of the operators and therefore should not be used without special protection for the backs of the men using them. They are not recommended because of mechanical difficulties encountered in their use.

2. *Continuous Pressure Hand Sprayers.*—The continuous pressure (1 or 3 quart) insect sprayer is the best piece of equipment available for DDT larviciding; at least in areas where small bodies of water such as road ruts, shell craters, fox-holes or artificial water catchments, constitute the principal breeding water. As much or more area can be covered with these sprayers with two to three quarts of DDT solution than with three to five gallons in a knapsack or cylindrical sprayer. Also, the area can be treated with less effort and can be covered faster with these small sprayers than with the larger types. This sprayer can also be used for applying repellents to clothing. Even the small hand sprayers, flit-gun type, are being used effectively in the field.

3. *Power Sprayers.*—Any type of power sprayer is convertible to application of DDT. Where fog is not desired the pressure should be cut down and the size of aperture increased. Paint sprayers usually produce a fog-type spray and are not very satisfactory for treating road ruts but can be used in treating large bodies of water (i.e., by wind drift of the fog-type spray). Camouflage liquid pressure paint applicators produce a fast coarse spray, very useful in residual work. The liquid pressure sprayers have adjustable pressures and the optimum pressure for a given nozzle must be determined by trial.

4. *An Improvised Power Sprayer,* for a weapon carrier or pick-up truck can be made using a portable air compressor, a heavy oil drum, a hose, a valve and nozzle. A three foot pipe welded through a 2-inch plug, will permit the drum to be set up vertically. The air compressor is connected to the small bung, the pipe inserted through the large bung and the plug screwed in tight. Thirty to 50 lbs. pressure is satisfactory. The M-10 CWS airplane smoke tank has also been used in a similar manner.

DUSTERS

1. *Rotary or Bellows Type.*—The rotary hand dusters are used for distributing DDT dust to large areas. Those provided are in general not very satisfactory. The "Root C-3" is the only one which has given satisfaction to date.

2. *Hand Pump Plunger Type.*—The small plunger type dusters available are excellent for dusting small bodies of water such as rain water barrels and shell craters. The plunger duster can be modified for roach control work so that locations difficult to reach can be treated. This is done by placing a piece of rubber hose (sprayer hose) six to ten inches long over the nozzle of the plunger duster, and attaching a piece of metal tubing flattened at one end for a new nozzle. The flattened nozzle can then be pushed back into cracks and the dust forced into the smaller crevices. If the delivery tube is off center, the duster should be rotated so the tube is uppermost. When provided with a long delivery nozzle, these dusters are used for mass treating of personnel for body lice.

3. *Foot Pump Dusters.*—The cyanogas foot pump duster provides a convenient intermediate size dust applicator, which may be used to advantage in latrine pits or in rat holes.

4. *Improvised Models.*—Small power dusters for mass delousing, etc., are easily improvised. Connect a source of air pressure through a valve to a fruit jar which has two small pipes soldered through the lid. Fill the jar ⅔ full with powder. If the delivery outlet is off center delivery can be regulated to some extent by tilting the jar.

Brushes.—Applying DDT to screens, ropes, cords, etc., is important as insects frequently alight there. But spraying such surfaces is very wasteful. These should preferably be painted with paint brushes 4 to 6 inches wide.

CONDITIONS AFFECTING THE USE OF DDT

Rain.—Although DDT as a residue tends to stick to surfaces, a considerable amount is washed away by repeated or heavy rains *particularly if the spray has not had time to dry.* Once a good residual has been laid down and dried (DDT in kerosene is preferred) heavy rains will not rapidly destroy its killing power. Such a residue on leaves of plants has remained effective after 1500 inches of artificial rain. In areas of heavy rainfall, DDT larvicidal applications are frequently flushed out when the water overflows.

Wind.—If favorable winds of low velocity prevail, dusts and fine sprays may be drifted by the wind over an area to be treated. This is particularly helpful in treating large water surfaces and in air applications. If the hand sprayers deliver fog-type

sprays, care must be taken to allow for the wind drift. *For contact kill the fine dispersal, smoke, aerosol, or fog* is the most effective PROVIDED it does not drift away too rapidly.

Vegetation.—Vegetation tends to prevent the wind from disrupting the uniform surface coverage of larvicides thus making larvicidal treatments longer lasting. When vegetation is excessively dense, heavier applications of larvicides may be necessary. No vegetation sufficiently dense was seen in the South Pacific to prevent complete control of mosquito larvae with the standard application of 0.2 pounds of DDT per acre when delivered with the Husman-Loncoy spray apparatus from cub airplanes. These situations were probably as difficult as any to be encountered elsewhere in the Pacific.

Dust and Salt.—When residuals are applied they usually remain effective until dust or other material covers the DDT deposit thus making it impossible for the insects to contact the DDT sufficiently to obtain a toxic dose. Buildings near the beaches are subjected to salt spray that tends to cover the DDT. In these cases it is necessary to reapply the residual treatment at more frequent intervals. If the surfaces to be treated are covered with dusts or other materials, they should be cleaned previous to application of the DDT.

Washing.—Bulkheads, screens, and other surfaces treated with liquid or dust forms of DDT for residual effect should not be washed unless absolutely necessary. Surfaces washed or repeatedly wet will require more frequent application of DDT.

Effect of Surface on Residual Treatments.—The nature of the surface upon which DDT is applied affects the residual killing power. Untreated canvas, bed nets, other cloth, and unpainted wood are especially effective after being sprayed with solutions or emulsions of DDT. Tiny crystals of DDT form on each fiber. DDT residue applications are less effective on canvas treated with antimold or water proofing compounds, and on painted wood (especially freshly painted surfaces). DDT dust is very effective on rough surfaces where it can cling, but as it will be washed off most outdoor surfaces, reapplications must follow each rain.

DIRECTIONS FOR THE USE OF DDT AGAINST MOSQUITOES

ADULT MOSQUITOES

Residual Effect.—Residual DDT, applied to surfaces on which mosquitoes walk or rest, can do more to break the cycle of mosquito-borne diseases than any other single local use of DDT. This use of DDT offers a rapid control measure for such diseases and can be initiated before permanent insect control is possible.

1. *Bed Nets or Jungle Hammocks Are Easily Treated: The rate of application to bed nets should be 6-7 bed nets or 30 jungle hammocks per gallon of 5 percent kerosene solution or emulsion.* The procedure for spraying bed nets with hand equipment is to spread and pile one on top of the other. The top net is sprayed on one side, *mesh only,* and reversed to start a new pile and sprayed on the opposite side. A second sprayer to spray the nets after they are turned is desirable. Five men can work rather efficiently in this operation; one to operate the sprayer, two to turn the nets for the new pile, and an additional two men could start a new pile of nets for spraying. One sprayer can treat about 60 nets an hour.

The procedure for spraying the netting on the jungle hammocks is for two men to carry the hammocks between two spray guns. Each sprayer covers one side of the net and his share of the end. Ten men are needed. Four groups of two each will be needed to carry a steady procession of nets past the two sprayers. About 450 to 500 nets an hour can be treated with this method.

Each man should take his own net from the treated pile and hang it up to dry. The nets should be dried until no odor of kerosene is detectable. One day in the sun should be sufficient. *If each man does not care for his own net, a detail of two to three times the number required for treating the nets will be required for handling the nets.*

Bed nets can be impregnated easily in Chemical Warfare Service equipment and where large numbers are to be treated this method may be utilized. The equipment and the concentration of the DDT solution or emulsion should be adjusted so as to leave 1¼ ounces in the meshes or 2½ ounces in each net, if a large muslin border is included. Nets or tapes made in part of rayon or other synthetic materials may be damaged by special solvents.

2. *Tents and Huts.*—Tents should be sprayed as soon as practicable after being set up, or better still, in the staging areas before mounting. Use

approximately 3 quarts of a 5 percent solution or emulsion per 16 x 16 pyramid tent. Huts and galleys should be treated. The rate of application for building surfaces should be 1 quart of a 5 percent solution or emulsion to each 100 to 400 square feet. The actual amount used should be sufficient to wet the surface just short of dripping. An effort should be made to spray all surfaces, giving special attention to the corners and other favorite resting places of the mosquitoes. *Treating of screens with DDT is a most important part of the treatment of huts and should be done immediately after the screens are installed.* Such surfaces as screens and netting are best treated with paint brushes.

3. *Native Huts.*—The BEST point to apply DDT to break the malaria and filariasis chain is residual treatment of interiors of native huts. The power sprayer of the liquid pressure type or the cylinder type sprayer equipped with a medium to coarse spray nozzle will do a fast job. A few seconds dusting with a rotary hand duster to give a dust cloud in the room will give a residue lasting several weeks and is the most rapid method.

4. *Residue on Vegetation.—If* mosquitoes are thick around small isolated posts, a heavy residue of dust or spray in sufficient amounts to apply 3-10 lbs. DDT per acre may be used. In rainy climates the spray would be preferred. This procedure is costly in materials and man power and is not advised for wide-scale use except in very critical situations.

CONTACT KILL

1. *Hand Sprayers.*—A 1-percent solution of DDT in kerosene or a 1 percent water emulsion, used in a hand sprayer is more effective than standard insect sprays though not as rapid. The G. I. insect sprays can be greatly improved by dissolving about 2 ounces of DDT to each gallon of spray.

2. *Power Sprayers.*—For *contact* kill the finest spray possible should be used. For treatment of a large area, a power paint sprayer can be used to produce a fog. Mounted on a vehicle, and driven slowly through an area in swaths, *it will be effective if the breeze is not perceptible.* A slow drift is desirable. Almost complete elimination of mosquitoes from heavily infested areas has been obtained with one quart of a 5 percent kerosene solution or water emulsion per acre.

3. *Smoke Machines.*—This is the ultimate in finely divided spray particles, and should prove useful where meteorological conditions are suitable (wind velocity, wind direction, inversion conditions, i. e., proper settling characteristics).

4. *Airplane Contact Kill.*—Details of this method will be covered in the Airplane Bulletin.

5. *Aerosols.*—Whether pyrethrum or DDT is used, aerosols are *inefficient in tents or huts if an appreciable breeze is blowing through.* They are advised only in spaces that can be closed, e. g., airplane compartments and huts, or in tents on still nights. The recommended dosage printed on the aerosol container should be followed, as various types have different delivery rates. When an emergency exists, excessive dosages may be warranted. An important use for aerosols would be the mass treatment of all buildings when rapid elimination of mosquitoes is necessary to prevent or stop mosquito borne epidemics. Out-of-doors, if wind conditions are such that the aerosol will not be blown out of the area, a one pound aerosol bomb may clear up an acre plot if carried back and forth through the area in swaths 20 feet apart. No residual effect will result.

6. *Dust.*—Dust makes an effective contact kill. Generally it will *not* be used solely for contact kill as it clings well only to rough surfaces and only acts as a good residue in protected places. Five pounds of *1 percent* dust per acre have given a good contact kill in densely wooded areas. To apply the 10 percent powders, adjust the dusters to deliver 1 to 5 pounds of dust per acre and apply in swaths 20 feet apart across the area to be treated. The swaths should be cross wind when possible. The dust can also be blown into buildings in sufficient quantities to make a good dust cloud. This method provides a very rapid way of killing adult mosquitoes in buildings or in limited out-of-doors areas.

7. *Size of Area.*—With area control of adult insects, the duration of effect depends on the size of the area treated and the speed with which the insects infiltrate again. Because of the large area cleared up, one application by airplane may last for days or weeks, in the case of mosquitoes, depending on the movement of the species.

LARVAL MOSQUITOES

Larviciding With DDT.—A mistaken impression on the part of many is that the main advantage of using DDT as a *larvicide,* over older methods using oil alone, is that a lasting residual effect is obtained. Actually, larviciding of water surfaces with DDT in oil is usually only slightly more lasting in effect than by using oil alone. The great advantage of DDT solution is that one gallon applied properly to a given area of water surface will give as good a kill as the 40 or more gallons of oil formerly necessary when applied without DDT. The advantages of DDT are a saving of oil, and of time and effort in application.

Before placing DDT in routine use sprayer personnel used to the old methods must be restrained from flooding surfaces as formerly was necessary with simple oil solutions. Actually DDT sprayers must move rapidly, using a fine spray which gives a light film which would be almost totally ineffective with oil alone. Workers used to the older methods will only with difficulty be convinced that such light applications of DDT will actually do the job. Have them begin with minimum dosages and observe the appearance of the film, particularly its lightness. Then have them check for larviciding effect within 24 hours after applying the film. By this method extremes of either over-application, or of under-application (rare) will be eliminated.

The long-lasting residual effect which seems originally to have impressed everyone as the most important advantage of DDT as a larvicide can be realized only by use of an emulsion applied not just to the surface but by mixing so that the emulsion is distributed throughout the total *volume.*

OIL SOLUTIONS

1. *Dosage.*—Although one quart of a 5 percent DDT-oil solution (or emulsion) per acre (0.1 pound DDT per acre) is an effective larvicidal dose, equipment in the field is not available for such low deliveries. Dosages above 0.2 pounds of DDT will probably result in negligible increase in larval mortality and will merely waste DDT. To avoid waste, various concentrations may be used depending on the delivery rate of the available equipment. *With knapsack or cylindrical sprayers supplied with the proper nozzles, a recommended dosage is five quarts of a 1 percent solution, and with the continuous pressure sprayers two quarts of 5 percent per acre.* In sewage effluent the dosage for *Culex* must be increased often as much as five times the minimum required. Again it is emphasized, to get these low applications the men *must keep moving* with the sprayer and not stop to "oil" individual water areas. In actual practice on one base the following dosages were applied:

Sprayer	*Gallons per Acre*
Knapsack or 3 gallon cylinder type with whirlplate nozzles	5–7
Continuous pressure hand sprayer	1–2
Airplane	½

The applications as shown above all did about the same job, all were equally effective, and all are considerably in excess of the minimum effective rate of less than one quart per acre. The variable amounts used were due to the inherent mechanical difficulty in dispersing solutions as lightly as would be desirable. However, with labor not too skilled or interested, or where careful supervision is not given, these figures may represent expected dosages.

For a *semi-prolonged larvicidal effect* where wind and waves cannot affect the surface, a dosage of 2½ gallons of a 5 percent oil solution may be used. Situations where the residual action may be expected by heavier *surface* treatments are uncommon. Where such applications are made, a routine check of the treated area should be maintained to determine when re-treatment is necessary.

2. *Frequence of Application.*—Treatments will usually require repetition at weekly intervals but the most effective re-treatment intervals are established only as dictated by frequent larval checks. During dry seasons, when rain does not flush or wind disturb the film, there may be a persistent enough of a film to considerably prolong the intervals of re-application. Due to all the variables such as vegetation, rain, wind action, wave action, etc., the lasting effects can rarely be relied upon.

3. *Oil Solutions by Other Than Spray.*—Drip, pouring or sawdust applications of DDT in oil to water surfaces are unreliable. A thin film can be made only by a very fine spray.

Emulsion.—Emulsions for *surface applications*

are used in the same manner and dosages as oil solutions. The emulsion tends to remain at the surface when applied as a fine spray, consequently the volume of treated water need not be considered. A prolonged *residual effect* may be obtained in water, that does not change greatly in volume or does not flush, by mixing the emulsion *with the entire volume* of the water to be treated so as to produce one part DDT per million parts water by volume. Generally the number of static waters in which truly prolonged residuals may be established are few. Examples are water in shell holes, foxholes, fire barrels, etc., which when treated in this manner, may have control lasting weeks or months. Apply a 5 percent emulsion by sprayer, at the rate of 5½ gallons per acre foot, or ½ cc. per cubic foot, and stir it up by wading or with a stick or dipper. An oil drum used as a fire barrel will require 4 cc. of 5 percent emulsion, (about one teaspoonful). *Mix well* with a paddle or dipper.

Dusts.—DDT dust is effective against anopheline *larvae* at a dosage rate of 0.1 lb. of pure DDT per acre. Heavier applications are necessary for the control of culicines. With available rotary dusters, an operator walking very fast can hardly cover an acre with less than 2 to 5 lbs. of dust. If no diluents are available, use the 10 percent powder undiluted; adjust the duster for a low delivery. Suitable diluents are rarely available in the tropics, but if dry fine dust can be found, dilute the 10 percent DDT down to 2 percent and apply at the rate of 5 lbs. per acre. Small plunger type dusters are excellent for work inside the camp, treating stacks of tires, small piles of tin cans, fire barrels, foxholes, etc. A fire barrel dusted with a half ounce of 10 percent dust before being filled with water may be effective against all types of mosquito larvae for several weeks. An oil spray residue is effective in rain barrels in the same way if permitted to dry before water is added. *DDT concentrate powder must never be used for dusting; the particle size is too large.*

DIRECTIONS FOR THE USE OF DDT AGAINST FLIES

ADULT FLIES

Residual Applications.—Residual use of DDT is probably more effective against adult flies than any other group of insects.

1. *Oil Solution or Emulsion.*—The solution in kerosene or the water emulsion may be applied to any surface where flies are observed to rest. This will certainly include *first of all the screens of all galleys, mess halls, latrines and garbage racks.* The residue applications would be especially useful in combat areas during the assault phase when it is largely impossible to control fly breeding with the more permanent sanitation methods. Dead bodies, garbage, spoiled foods, and feces sprayed with DDT will kill adult flies that come to feed or rest on the treated surfaces. Vegetation around dead bodies, or wastes may well be treated if the flies rest on it. In mess halls and galleys, flies will enter through the open door, but if the building and screens have received a residual treatment of DDT the flies will be dead before the next meal.

Latrine boxes may be sprayed, both inside and out. Directions for residue painting of screens and spraying of solid surfaces are those found under "Equipment for Application of DDT". A modification of the standard latrine box may prove effective. Remove a board from either or both ends of the latrine box, preferably in a light spot, and replace it with screen wire. If a lower board is removed the screen must be protected to prevent its being kicked out. Paint the screen wire with DDT in kerosene periodically as needed. This will poison flies both as they try to enter and as they try to leave the box. As the lethal effect may take several hours the latrine box may be full of incoordinated flies, especially at the morning rush hour. This may be annoying but should not lead to doubts about the efficacy of DDT. Mosquito netting in temporary galleys and latrine shelters should be treated. It may be treated more economically before it is put in place.

2. *Dust.*—Dust residue is unusually effective against flies. An advantage of using powder is that it can be applied much more rapidly than a spray and will therefore be a useful control measure for critical situations. A disadvantage of the powder is that it can be applied much more rapidly than a spray and will therefore be a useful control measure for critical situations. A disadvantage of the powder applications is that they are more apt to be blown or washed away than the spray residues. Dust residues are effective in rough buildings such as barns, stables and native huts or on any rough surface not reached by rain. They are useful on the ground around garbage stands, the earthen walls of latrine pits and even on vege-

tation. It is necessary to re-treat vegetation following each rain.

Contact Applications.—Although flies are more rapidly affected by DDT residue than mosquitoes they require higher dosages of contact applications.

1. *Oil Solutions or Emulsions.*—DDT sprays are more effective against flies than the standard sprays and are used in the same manner as against mosquitoes. In mess halls, latrines, etc., residue applications will be more practical for use than the fly sprays.

2. *Dusts.*—DDT dusts can be used against flies in the same manner as against mosquitoes.

3. *Aerosols.—Pyrethrum aerosols are not recommended for use against flies.* Unless dosages greatly in excess of those recommended for mosquitoes are used the flies will only be "knocked down" by the pyrethrum and will recover. When DDT aerosols become available the recommended dosages will kill flies as well as mosquitoes.

4. *Airplane Applications.*—Since maggots and pupae are both protected from the effects of airplane applications, this method of control is effective only against adults. Unless it is shown that effective DDT residues can be applied by aircraft sprays, re-treatment must be sufficiently frequent to kill the adults as they emerge.

FLY LARVAE

Residual Applications.—The residual types of application for DDT are not effective for fly larvae control. Large amounts of dust or oil solutions added to feces in latrines has not given adequate control. In latrine pits, fly larvae try to crawl up and out of the pit in order to find a better place to pupate. Here they may be killed by a heavy residue of 10 percent dust on the earth sides, *provided* it does not get washed away by rain or urine. Both in latrines and on dead bodies sodium arsenite appears to be more effective against fly larvae than DDT.

Contact Applications.—DDT solutions are highly toxic to fly larvae and are effective when applied to small dead animals or small pieces of meat. Under these conditions DDT appears equal to sodium arsenite, but when applied to the larger dead bodies or to large fecal masses, it fails to give satisfactory control of maggots. However, if sodium arsenite is not available considerable good may be obtained from the use of DDT. Some maggots will be killed and the residual DDT will kill adults. At the present time, sodium arsenite is recommended for fly maggot control.

DIRECTIONS FOR THE USE OF DDT AGAINST BEDBUGS

DDT Is the Perfect Answer to the bedbug problem. When properly applied to mattresses and bunks, barracks will remain free of bedbugs, for 6 months to a year, or more.

Dosage.—Five percent solution in kerosene or 5 percent emulsion is recommended, using about one-half pint per bed, including mattress, pillow, springs, and the joints in the bed frame; 3 to 5 gallons (1.2 to 2 lbs. pure DDT) per 100 men should be ample.

Technique.—1. Remove or protect articles made of rubber and leather that might be injured by contact with kerosene.

2. Use a power spray rig for large scale operations, and a fan shaped spray nozzle adjusted to give a medium droplet size. Fog billows away in air currents and is lost. Continuous pressure hand sprayers can be used but are slow.

3. Operators are advised to wear masks to avoid irritation due to kerosene and excessive inhalation of DDT. The risk is not great, however. Some ventilation is absolutely necessary. All smoking must be prohibited while kerosene is being sprayed and for some hours afterwards. *Gasoline Must Never Be Used!*

4. Mattresses should be placed in a pile. The outside of the pile is then well sprayed. Most of the bugs are found in the folds. The top surface of the top mattress is then sprayed lightly; a slight moistening of the surface is all that is required. An assistant quickly turns it over, preferably onto another pile, where the opposite side is sprayed. A second operator may be used for this phase of the work. Pillows are sprayed lightly.

5. The bunks are placed vertically against the wall, and sprayed paying particular attention to the joints. Canvas should all be sprayed. The spray should be directed so that the portion which misses the bunk will hit the wall.

6. When spraying is complete, return mattresses to the bunks. After 4 hours airing the bunks may be made up and used.

7. *Special Notes.*—Emulsion is recommended for upholstered furniture because it is non-staining, and aboard ship, because of the lower fire hazard. It may sometimes be advisable to spray the inside of barracks bags. It is always well to spray mattresses of men entering a barracks, if the mattresses have not been previously treated.

8. Sprays are preferred, but dust may be used for individual infestations where spray equipment is lacking.

DIRECTIONS FOR THE USE OF DDT AGAINST LICE

DDT has made possible a simple and effective control of louse-borne diseases. Lousiness is destructive to morale at all times and is always a serious health hazard. It is controlled by (a) individual dust applications, (b) mass dust applications, (c) impregnation of clothing. Head lice and crab lice are as easily and safely controlled as body lice.

Individual Dust Application.—A liberal application of the powder (10 percent DDT) from the two ounce sifter top can, should be made over the surface of the underwear, (or trousers and shirt if underwear is not worn) paying particular attention to the seams. It should be rubbed in and distributed well by hand. *Approximately one ounce or half a can will be necessary for one application.* The effect remains until the clothing is changed or washed. While it is better to have the clothing removed, the seams, particularly the armpits and crotch, may be dusted effectively by merely unbuttoning the shirt and trousers. A light dusting of the bedding is also desirable.

Mass Dust Applications. 1.—Where a large population is lousy, mass treatment is faster and more certain. Use either a plunger type duster or a small power duster. If the plunger type duster with offset nozzle is used, the delivery tube should be uppermost.

2. Men doing the work for the first time should make a few test applications, have the clothing removed, and inspect the person and clothing. If the dusting has been well done, the inner clothing should be well powdered, especially the seams of the neck, armpits, waist, shirt tail and crotch. The hairs of the chest, back, thighs, armpits, pubic and perineal regions should also show powder.

3. A definite routine should be followed on each person being dusted.

a. Dust inside of hat and replace on head.

b. With arms extended to the sides at shoulder height, insert delivery tube up first the right and then the left sleeve, pumping powder between the skin and inner garment. Powder should reach into the armpit, and the position of the gun should be shifted to get powder all around the shoulder.

c. If several layers of clothing are worn, dust should also be applied between the undershirt and the shirt.

d. The delivery tube is then inserted at the back of the neck, powdering the entire back *and* the neckband.

e. The tube is inserted next inside the clothing from the front, powdering one side, then the center, then the other side, taking care to reach the armpits again.

f. The trousers are loosened and the tube inserted next to the skin. A good dose of powder is blown into the seams of the crotch and the pubic hairs. With the tube still in place the underclothing is dusted, special attention being paid to the waist and sideseams.

g. With the trousers still loose, the tube is inserted down the rear of the pants, next to the skin and powder shot down over the buttocks and rear of the crotch.

h. *Note:* If more than one layer of clothing is worn, steps 3, 4, 5, 6, and 7 above should be repeated for the next layer of clothing.

i. Although 95 percent of the lice are generally to be found on the person or the clothing being worn, other clothing and bedding may be infested, thus providing a source of re-infestation. In dusting clothing or bedding, always have the delivery tube between layers of cloth, thus conserving dust, and powdering two sides at once. Cover a mattress with a blanket and blow powder between the two. Folded blankets are piled, dusted between each layer, and pounded to fluff the powder through the blankets.

Dosages.—The amount of DDT 10 percent dust required for dusting a person varies with the amount and type of clothing worn. The average adult in fall or winter clothing should require not

over 1½ ounces. Supervisors must check to prevent exceeding this amount. Bedding may require more than clothing. Where men are under discipline, a team of two men with hand dusters can dust about 35 to 40 men and their bedding, per hour, if the men help with their own bedding.

Mass Impregnation of Clothing.—1. *General:* This method appears to be most certain, at least when dealing with heavy underwear. Such underwear impregnated by dilute (2 percent) emulsion, with a total weight of DDT equal to 2 percent of the weight of the dry garments, remained lethal to lice after 6 to 8 weeks of wear with one washing per week. It seems probable that these results would not be obtained with light weight underwear. For tropical use, the shirt and trousers would be treated in a similar manner.

2. *Technique.*—Impregnation may be done by the use of solvents such as dry cleaning solution and the use of emulsion.

a. When dry cleaning or Chemical Warfare apparatus is available, impregnation by solution of DDT in gasoline, or Stoddard's solvent is very satisfactory. The percentage of DDT in the solution should be adjusted so that the amount of solvent left in the clothing after wringing out, will leave a deposit of 15 to 20 grams (½ to ⅔ oz.) of DDT in the clothing.

b. Similar rules apply to the use of emulsion. The emulsion concentrate contains 25 percent DDT. It will be diluted with water to a concentration of 1.5 to 2 percent DDT. *Dry clothing only will be immersed.* A lyster bag and hand operated clothes wringer are easily improvised for field impregnation. Standard laundry equipment is very satisfactory. Whatever amount of water is left in the clothing, the garment should receive 15 to 20 grams (½ to ⅔ oz.) of DDT, or 60 to 80 cc. (2 to 2⅔ oz.) of the emulsion concentrate.

c. Individual impregnation can be accomplished by mixing 2 ounces of emulsion concentrate in a helmet with just enough water to wet the clothing to be treated, but not to the point of dripping. The clothing is then dried thoroughly. Rain must not get on it while drying.

Body Spray for Lice.—1. DDT does not affect the louse eggs which are sometimes attached to hairs of the body. Consequently, unless the same clothing is worn for a week after dusting, delousing may fail. It is often desired to delouse prisoners of war quickly both as to adults and eggs. To give a complete delousing in one day, a delousing solution has been prepared and is in use by the Army. *This is "Insecticide, DDT, spray, delousing"* (68 percent benzyl benzoate, 6 percent DDT, 12 percent benzocaine, and 14 percent emulsifier Tween) and before use it is *diluted 1 part of concentrate to 5 parts of water.*

2. *Technique.*—Prisoners are stripped and while their clothing is being deloused, they are given the spray treatment. The spray is applied by power spray and paint spray nozzle to all hairy portions of the body including the head (*About 20 c.c. (⅔ oz.) of spray is required for this treatment.* The individual holds his fingers over his eyes to prevent the spray getting into them. He is instructed not to bathe for 24 hours. This treatment kills all the eggs and lice it hits, and the residue may later affect some which have been missed.

Head Lice.—DDT powder dusted in the hair and rubbed in with the hands will kill growing and adult head lice. *The hat should also be dusted (especially inside hat band). Since DDT will not kill the eggs, the treatment should be repeated 7 to 10 days later.* The hair *must not* be washed for 24 hours, and preferably should not be washed for 2 or more weeks. Keeping it dusted will prevent re-infestation. Delousing spray may be used effectively. Rub 10-15 c.c. (⅓ to ½ oz.) into the hair, and preferably do not wash the hair for two weeks.

Crab Lice.—The same treatments as are recommended for the control of head lice are also effective for crab lice. It is highly important that *all hairy portions of the body be thoroughly treated,* as a few areas left untreated may harbor too few lice to be noticed but enough to re-infest the entire body.

DIRECTIONS FOR THE USE OF DDT AGAINST OTHER PESTS

Scabies.—The delousing spray is also effective against scabies. It should cover the entire body except the head. Any untreated or poorly treated area may serve to maintain the infestation and result in an unjustified disappointment in the

agent. The dilute solution may be applied with a sponge, piece of cotton flannel, by means of a sprayer, or simply by pouring it into the hands and rubbing it on. *One application has been found to eliminate the infection in 24 hours,* with no bath required. If a second treatment is found necessary, it should be made 5 to 7 days after the first. One treatment requires approximately 50 cc. (1⅔ oz.).

Fleas in Buildings

1. *DDT* sprays have been found highly effective on fleas in buildings. The sprays should be applied on the floor and about 2 feet up on the walls at *1 quart per 200 to 400 sq. ft.* The actual amount to use depends on the surface to be treated.

In living quarters, beds and bedding should be sprayed lightly also. On earthen floors the dosage must be considerably higher because the DDT becomes covered with dust, making much of it not available for contact with the fleas.

2. *Dusts are quite effective* on both hard and earth floors. It should be applied to beds and bedding at the same time.

Fleas on Animals.—The DDT insecticide powder can be used on animals that are infected with fleas. Due to the toxicity of this material it should be applied *very lightly,* especially to animals that lick themselves. To apply the powder, part the hair and dust lightly on the skin in a number of places on the body, particularly back of the head and neck, under the throat and on the ears. The animal's bed may be *lightly* dusted. *DDT should be used in rat harborages for plague control where cyanide dust may not be used.*

ROACHES

Ten percent dust is preferred.—It should be blown into their favorite hiding places, such as in cracks and behind objects, behind and under drawers, etc. It is best applied with a small plunger type duster with the tip of delivery tube flattened. Some roaches are very resistant, and may run around in the open for a day or two in a slightly intoxicated condition, after contacting DDT, before succumbing to it. Thus it may appear that DDT has temporarily increased the number of roaches. Residues from oily sprays are less effective on roaches than the dust.

Ants.—Ants are a great pest, though not a cause of disease. A hut will be remarkably free of ants after a residue spraying or dusting has been applied. To keep ants from establishing colonies in gas mask bags, sea bags, etc., it is recommended that the walls of such bags be lightly dusted or sprayed with DDT in kerosene or as the emulsion. Dry such containers thoroughly after spraying.

Mites (Chiggers).—While DDT will eventually kill mites and chiggers, its action on these insects is too slow to form a safe protective application on clothing. It can be used to treat infested ground. Considerable protection from chiggers may be given to men in small bivouac areas by dusting the area heavily (5 to 10 pounds per acre) with the 10 percent insect powder.

Ticks, Spiders, and Centipedes.—DDT has been reported as killing some of these anthropods, but it should not be depended upon to do so in ordinary doses. DDT applied as a 5 percent spray (5 to 10 pounds per acre) or 10 percent dust (5 to 10 pounds per acre) to all vegetation in a bivouac area will give control sufficiently adequate to warrant its use if ticks are unusually abundant. DDT dusts and DDT emulsion applied as a light wash to animals will kill nearly all the ticks that are attached.

Sand Flies.—Sand flies such as *Culicoides* or *Leptoconops* may be controllable by selective residual treatment with dust. Their breeding places are usually strictly limited and must be accurately determined. These are often narrow bands of mud flats covered at the highest tides only a few days out of the month. Or they may breed in certain other muddy places. Probably the application of dust to known breeding spots is a measure well worth trying. A few favorable reports have been noted. Because of their variable periods of emergence ANY control measures may happen to precede a marked drop in incidence. Treated bed nets and screens will poison these insects as they make their way through the meshes. They will not be killed in time to protect completely the man inside the net or room, but they are affected soon enough to give considerable protection from bites.

Miscellaneous Insects.—Insects small enough to crawl through screen wire receive a toxic dose of DDT if the screens are treated with DDT. Although complete elimination of insects is not

secured, the reduction in annoyance makes the treatment worthwhile.

ARSENIC AND OTHER CHEMICALS

SODIUM ARSENITE

General.—Sodium arsenite in 54 percent concentrated solution (Trade name, Penite-6) has recently been widely used in the Pacific on dead bodies, feces, rotting foods and other concentrated fly breeding locations, for fly control. It is a powerful and cheap fly maggot poison.

Precautions.—This material is very toxic to humans and the men need instruction as to its dangers. There is danger of absorption through the skin from leaky sprayers and it may cause a skin rash. If the concentrated solution should be spilled on the skin it should be washed off immediately.

Sodium arsenite is also a strong stomach poison and the proper precautions should be taken around foods and food stores and water supplies and to prevent poisoning of domestic animals.

Antidotes.—The new arsenic antidote, BAL ointment for external use, BAL liquid for internal use, should be available. If these materials are not obtainable, use emetics such as soapy water followed by internal administration of ferric hydroxide.

Action on Insects.—Sodium arsenite is a stomach and contact poison. It will kill both maggots and adult flies. Experience in the field has indicated that when sodium arsenite is sprayed on dead bodies or on foodstuffs the adult flies feed sufficiently to kill large numbers.

Equipment to Use.—Both hand and power sprays have been used. The nozzle and pressure should be adjusted to provide "wet" spray only, no fog. Since speed is usually important, a coarse spray nozzle such as the double head nozzle of the cylinder type sprayer is desirable. For treatment of masses of dead bodies, wrecked enemy food dumps, straddle latrines, etc., a 50-gallon truck-mounted power sprayer is desirable.

Dosage and Method of Application.—If 54 percent concentrated solution of sodium arsenite is provided, mix one gallon with 40—80 gallons of water. Fresh, brackish or sea water may be used. The latter tends to precipitate some arsenic, necessitating stirring, and tends to cause rapid rusting of equipment.

1. *In spraying dead bodies, the following technique is recommended.*—Spray the uppermost side of the body where it lies till thoroughly wet. Roll it over with a special rake or other tool, and wet thoroughly the reverse side. Approximately two quarts per body should suffice. An average burial detail will use a 30-gallon drum of concentrate on 1200 to 2000 bodies, treating a fair number of animal bodies and latrines at the same time.

2. *Treating Latrines.*—For quickly bringing a maggot infested latrine under control, sodium arsenite is ideal. No fixed dosage is advised. In latrine pits, where a considerable amount of water is present, a larger dosage is needed. In mushy or dry feces, a 1/80 dilution of the 54 percent concentrate, applied daily in a wide open latrine provides good control. Apply at the rate of one to two quarts per 16-hole latrine. Dosage should be governed by daily inspection of the latrines for breeding, using a strong flash light. Daily treatment is most sure, but every two or three days may suffice.

PARADICHLOROBENZENE

Paradichlorobenzene, PDB, has been used for fly control in the Pacific areas. The practical use of this material has caused considerable debate and at the present time it is not clear just how PDB should fit in an overall program.

Precautions.—Three sources of irritation should be noted:

1. In shallow pits the vapors of PDB cause a burning sensation of the genitalia.
2. If PDB clings to the fingers and is rubbed into the eyes it will cause a serious eye irritation.
3. If PDB crystals are spilled on the seat, skin burns may result.

Action on Insects.—Paradichlorobenzene is a slowly volatile white solid with characteristic odor. The granules give off heavy vapors which tend to remain in the bottom of the latrine pit. The vapors in moderately heavy concentration not only repel adult flies, but also act as a fumigant to kill maggots, if they are present before treatment.

Limitations of Use.—The material is ineffective in open latrines, shallow pits or pits filled with water. It is satisfactory only if used in deep pits. As the vapors are readily blown out of pits it has been recommended that the ventilation ducts be closed where PDB is used.

Dosage.—The initial treatment for an 8-hole pit is 5 to 8 pounds. The average dosage should be two pounds (about 4 "C" ration cans full) for an 8-hole latrine, applied twice a week. Scatter the crystals along the edges of the pit. Since the ventilation of pits varies greatly it may be necessary to vary this dosage to fit the conditions.

MISCELLANEOUS CHEMICALS

Paris Green.—For many years Paris green dust has been an outstanding anopheline larvicide. DDT can completely replace Paris green as a larvicide and it has as an added advantage of being effective against both anophelines and culicines.

Sodium Fluoride.—Sodium fluoride has been a standard roach control chemical. However, its high toxicity to man makes it a dangerous material for general use. DDT can be substituted. However, certain species of roaches appear to be more resistant to DDT than others.

Methyl Bromide.—Early in 1942 methyl bromide fumigation methods were established both for individual and mass delousing of clothing. This is a highly toxic gas, and dangerously cumulative. DDT offers a safer and more practical way of controlling body lice.

Cyanide.—Until the effectiveness of DDT was demonstrated, the cyanide fumigation of buildings offered one of the few practical methods of eradicating bed bugs, fleas, and other household insect pests. Cyanide is so deadly to humans that it could be handled safely only by skilled workmen. DDT should be substituted for bed bug control and for flea control.

REPELLENTS

Composition and Form.—Three different liquid chemicals have been recommended for personnel protection against mosquitoes, biting flies and gnats, mites, fleas, and ticks. These three are, dimethyl phthalate, Rutgers 612 and Indalone. Each of these has been found very effective against certain groups or species of insects and ineffective against others. To provide an adjustment for the variation in species reaction to individual repellents, a material has been adopted composed of six parts dimethyl phthalate, two parts Indalone and 2 parts R-612. This is formula 6-2-2 and is packaged only in two-ounce bottles.

The standard issue repellents in the two-ounce bottles are all commercially pure chemicals and are not diluted with any other chemical. They may be identified as follows:

1. Skat, dimethyl phthalate. This material is the clear "Skat" and may be labeled 0-262 or dimethyl phthalate.

2. Skat, Indalone. This material is the yellow "Skat".

3. EverReady, R-612. This is a proprietary material and the chemical name is not given.

4. The 6-2-2 mixture. None of this material has been seen in the area.

The dimethyl phthalate in gallon cans is identical to that furnished in two-ounce bottles (clear Skat) and can be used in the same manner as the repellent in the bottle.

REPELLENTS FOR MOSQUITOES, FLIES, GNATS, FLEAS, ETC.

Complete Coverage Important.—The repellent must be uniformly distributed over all the skin area to be protected. The insects will seek out and bite any small area where the repellent was either not applied, or was applied too thinly, or was applied but rubbed off. *Men must be taught the proper method of application by demonstration.*

Precautions.—Repellents irritate eye lids, eyes, lips, and thin skin of the genitalia, resulting in a burning sensation. They are also solvents, and may dissolve paints and varnishes, plastic watch crystals and synthetic cloth.

Applications to Skin.—All of the repellents feel oily on the skin and are disliked by the men. However, there will be many situations where the men will have no other protection from insect bites. They should be encouraged to make liberal applications of the repellents. *The repellents*

should be applied at a heavier rate than the instructions on the bottle indicate. The material must be present as a rather thick film to insure maximum protection. Dry or hairy skin will require more repellent to provide complete coverage. No rule can be laid down as to the amount needed. It is a good idea to re-smear the repellent occasionally, to restore the covering where it has been sweated off or wiped off. It generally lasts longer on some areas than others.

1. *Liquids:* The most common method of using repellents from the individual bottle is to shake a few drops into the palms, smear evenly, then apply to the backs of the hands, wrists, neck, ears, face, much as in washing. Repellent should be worked over the fingers, carefully approaching the eyes and lips. The finger tips should also be used to smear repellent inside the ears and behind the ears.

A second way to use the individual bottle of repellent is to soak a cloth with the contents and tie it in a convenient location such as around the neck. The repellent may then be applied by either rubbing the treated cloth over the skin or by wiping the hands on the rag and then rubbing the hands on the area to be treated.

2. *Creams.*—The same amount of repellent liquid incorporated into a cream or powder base type containing zinc oxide will provide an application lasting up to several times as long as the plain liquid. Experiments are continuing for the development of an ideal base.

Applications to Clothing.—In some localities mosquitoes are so numerous that they cause considerable annoyance by biting through the clothing. For such conditions, repellents may be applied to the clothing where the bites occur. The treatment may be expected to last several days if the clothing remains dry. One soaking with water removes enough of the repellent to make the treated clothing non-effective.

1. *Hand Application.*—Under conditions where no equipment is available, fair protection may be obtained from applications made by hand. Shake about one-fourth teaspoonful into one hand, rub the hands together and apply lightly by rubbing hands on socks, shirts, or trousers where bites occur. Repeat this procedure until the areas to be treated have been covered.

2. *Sprayer Application.*—Probably the most satisfactory method of applying repellent materials to clothing is by means of a sprayer. Ordinary hand sprayers are satisfactory, but for large groups of men cylinder type sprayers or paint guns are preferred. A sprayer that delivers a rather "wet" type of spray is better for this purpose than one that delivers a "fog" or small droplet because a fog spray floats away. An application of about 2 to 4 fluid ounces on fatigue coveralls or upon a shirt and trousers is a desirable dosage. If more than 4 ounces is applied the clothing may be slightly "oily" and have a tendency to pick up dirt. Two methods of spray applications are suggested.

a. If the sprayer is of the "wet" spray type, the men can be sprayed with their clothing on, taking care that the men protect their eyes and do not breathe the spray material.

b. If it is necessary to use a sprayer of the "fog" type, there is considerable loss of material if sprayed on the clothing while on the men, but this loss can be largely avoided by spraying clothes while they are not being worn. This is rather rapidly done by spraying into garments that have been turned inside out and buttoned. One man can hold shut the opening of the legs of the trousers, while another sprays into these bag-shaped garments. The "wet" type of spray may also be applied in this manner.

REPELLENTS FOR CRAWLING INSECTS SUCH AS MITES, TICKS, FLEAS, ETC.

Mites.—The mite (chigger or red bug) is a cause of much lost time and great annoyance in many parts of the world. In some sections it is also the vector of a serious typhus-like disease, tsutsugamushi fever, (also known as scrub typhus or Japanese River Fever). *Due to the habits of the mite and the slow action of DDT, full protection is not assured by the use of DDT. Any of the G. I. repellents afford better protection both by repellency and lethal effect on the mites.* As dimethyl phthalate is the most readily available, it will be the one most generally used.

Methods of Application.—Dimethyl phthalate may be applied by hand. An over-all treatment of clothing may be applied by sprayer, or by immersing the clothing in an emulsion. Impregnations

with dimethyl phthalate in aqueous emulsions are not so resistant to removal by water as the applications of undiluted material using the spray or smear techniques. The treatments last days, or even several weeks if not washed out. Clothing, well impregnated, will remain effective against mites for 30 days if kept dry, for 15 days if exposed to moderate rains AFTER being dried completely. But one laundering or 30 minutes in running water will reduce the dimethyl phthalate to a non-effective level. Blankets should be treated every three months unless laundered or not kept dry. The important point is to treat the clothing BEFORE exposure to mites. This may be done immediately before exposure by methods 1 or 2 or several weeks before by methods 1, 2 or 3 below.

When troops are preparing to move into areas where scrub typhus is anticipated, the clothing, trousers, shirts, and socks should be treated. It is also usually advisable to treat blankets. Clothing and blankets may be treated prior to departure and stored in the sea bags provided they are not to be worn or used more than 3 or 4 days before the landing operations. If the treated clothing is to be worn more than 3 or 4 days before the attack, it would be advisable to treat on board ship.

Unless the troops are subjected to very frequent and heavy rains, or find it necessary to wade many streams, the suits should be re-treated every two weeks, or every week with extreme exposure to water. Clothes must be re-treated each time they are laundered. Blankets should be treated every three months unless laundered or not kept dry. The following four methods of treatment are suggested:

1. *Smear Method.*—The best simple method for the individual to treat his own clothing is to use the G. I. repellent issued in the two-ounce bottle. Shake about one-fourth teaspoonful of liquid into the palm of one hand, rub the hands together and then rub lightly on the socks and on the uniform. Repeat this procedure until one two-ounce bottle has been applied to a uniform. A rather uniform application can be made with this method if the hands are rubbed lightly on the cloth. If the hands are pressed too firmly uneven distribution will result. Apply repellent all over the clothes but most liberally along all openings of the uniform, inside of neck, fly, and cuffs of trousers.

The bulk dimethyl phthalate can be used instead of the two-ounce bottle. Pour the repellent in clean tin cans or other small containers. Several men can use one container at a time. The men may dip their fingers into the repellent, smear evenly over the palms by rubbing the hands together and then rub lightly on the areas to be treated.

2. *Barrier Method.*—A second method for the individual is to make a barrier with the two-ounce bottle or repellent. To do this, draw the mouth of the bottle along the cloth to apply a thin layer one-half inch wide along all openings of the uniform, inside of neck, fly, and cuffs of shirt; waist, fly and cuffs of trousers; socks above shoes and all of the leggings. One half of a two-ounce bottle of repellent should be used per treatment. The barrier applications may be made with a sprayer. Any of the hand sprayers may be used for these applications.

3. *Spray Method.*—This method will generally be preferred for mass clothing impregnation. It will take the least time, and present the least difficulty with drying. Either method (hand or spray application) may be used. The dosage is the same, 2—4 ounces per uniform; more than 4 ounces may leave it too wet. If done in the staging base, it is advised that *only such clothing be treated as may be packed and not worn until arrival at the target.* Otherwise a hand barrier application or a "wet" spray of the clothing on the person is advised just before landing where mites may be a problem.

4. *Immersion Method.*—This is a mass treatment procedure best suited for use in laundry or Chemical Warfare equipment. Dimethyl phthalate can not be dissolved in ordinary dry cleaning solvents, so dry cleaning techniques can not be used with this repellent unless the solvent is miscible with dimethyl phthalate. Emulsions made of 5 percent dimethyl phthalate 2 percent laundry soap and water to make 100 percent are satisfactory. They may be efficiently applied using standard laundry equipment. Repellent formula 6-2-2 *can not be used* with this emulsifier. The Army is adding an emulsifier to the repellent. To make a finished emulsion with this material, merely add the contents of the can to the recommended volume of water.

a. *Materials required to treat 100 uniforms with Soap Emulsion Method:*

Dimethyl phthalate	7.5 quarts
Navy or G. I. laundry soap	6 lbs. (approximately 7 cakes)
Water	35 gallons
55-gallon oil drum	1
35-gallon G. I. can or similar container	1
G. I. egg whip (wire)	1

The above materials are used to make 37 gallons of emulsion containing 5 percent dimethyl phthalate and 2 percent soap.

b. *Procedure.*—Cut soap into small pieces and boil in 10 gallons of water to dissolve.

2. Pour 4 or 5 gallons of this soap solution into a G. I. container, add 7.5 quarts dimethyl phthalate slowly while whipping vigorously with an egg whip to make a creamy concentrate.

3. Pour this concentrate back into the drum of soap solution and stir to make the finished emulsion.

4. To prevent settling, one man should keep stirring this emulsion slowly while clothing is being dipped.

5. Put socks in trouser pockets. Immerse clothing (including parts held in hands) in the emulsion and wring out over a second container to save excess liquid. Hang uniform out to dry.

NOTE.—To assure adequate treatment and to avoid diluting the emulsion, only dry uniforms should be dipped.

c. *Treatment of Blankets.*—Since a blanket absorbs about three times as much emulsion as a uniform, the quantities mentioned for 100 uniforms should be tripled for treating 100 blankets. Blankets are treated in the same manner as described for uniforms.

d. *Remarks.*—After the clothing is thoroughly dry, it can withstand wetting, but it should be protected from the rain during drying. A delay in the drying for a day or two under cover because of bad weather will not affect the mite-killing qualities.

Shorts should be worn under treated uniforms. Otherwise, the dimethyl phthalate may cause a burning sensation of the scrotum if the uniform should become wet or sweaty. No skin reactions of a nature serious enough to contra-indicate the use of impregnated clothing have been reported.

As underwear is frequently not worn by men in the tropics, a "wet" spray so directed as to avoid the crotch will be the preferred method of clothing impregnation.

Ticks.—The directions given for use of repellents against chiggers can be followed for ticks except that the application of the repellent as a spray at the rate of approximately 3 to 4 ounces (100 cc.) to the entire outer garment has proven more effective than the barrier treatment described for chiggers. The repellent treatment has been found highly effective against larval or seed ticks and moderately effective against the nymphal ticks. Results against adult ticks have not been as successful as desired, but some protection is obtained.

CHAPTER 7

NOTES ON WATER SUPPLY ASHORE

WATER SUPPLIES

The Problem of Pure Water.—A hygienically safe and continuously dependable water supply is one of the necessities of life. Water, like other natural resources, is procured as a raw material, manufactured into a commodity suitable for use and distributed to places of consumption. In North American cities the design of water works and their sanitary control by public health agencies have developed to the point that pure and abundant water supplies are accepted as the natural state of affairs. The provision of abundant supplies has been accomplished at great expense and the safety of these supplies is attained only by raising multiple barriers against the agencies of disease and by maintaining uninterrupted vigilance against the development of sanitary hazards. It is the responsibility of the Naval Medical Department to make sure that barriers to the spread of water-borne disease are adequate and that the creation of sanitary hazards through faulty design or practice is prevented. This responsibility implies a field of interest and activity beyond the testing of water samples.

Types of Water Supplies Ashore.—Water for Naval stations in the United States is often purchased from a near-by municipality. Since this is normally pure water, the water sanitation measures on the station are directed toward discovery and prevention of defects in the distribution system. Where municipal supplies are not at hand or are inadequate the Navy builds and operates the complete system which includes collection, purification and distribution works. Protection of the source and control of purification then assume an importance equaling that of preventing recontamination during distribution. The sources that may be utilized are rainwater, ground water, surface water or sea water. Ground water is commonly preferred but is an unreliable source because of the great uncertainty as to the quantity and quality of water which will be continuously available. Surface water is more abundant and is more susceptible to quantitative and qualitative study so is used for most large supplies. Rainwater and sea water find use at advanced bases when surface and ground sources are inadequate. The type of purification required depends on the quality and uses of the water, and may vary from simple chlorination to elaborate treatment to remove minerals as well as bacteria and other micro-organisms. The water purification works in permanent stations are similar to municipal plants. Equipment for advanced bases, on the other hand, is especially designed for lightness, mobility and simplicity of operation.

Quantities of Water Required Ashore.—The per capita consumption in shore stations depends on the climate, the standard of living maintained and on the extent to which water is used for industrial operations. In established bases with adequate bathing and laundry facilities water consumption for all ordinary uses will average from 75 to 150 gallons per capita daily (gpcd). A figure of 100 gpcd may be remembered as typical. To this amount must be added the quantities required for the operation of water-consuming industries or for supplying the fleet. The needs for fire fighting are cared for from stored reserves. Stored water also compensates for the continual fluctuations in demand, thus making possible the uniform and economical operation of pumps and treatment works. The distribution system is designed to provide for peak quantities, which may exceed the average by

several hundred per cent, and to supply large quantities of water for fire fighting where the potable supply is used for this purpose.

At well developed advanced bases water consumption generally reflects a compromise between a desirable abundance and a practical maximum for overseas operations. The maximum amount provided is usually around 50 gallons per capita daily. This quantity is decreased as the supply difficulties increase. At semi-permanent camps no more than 25 gallons per man per day is provided and under actual combat conditions or at newly established bases only a fraction of this amount can be made available. The minimum daily allowance of water in camps and on advanced bases is 5 gallons per man. When the supply is limited to this amount little if any potable water can be used for laundry and bathing.

In the field the uses of water are apt to be restricted to those that are absolutely necessary. One gallon per man per day may be taken as the absolute minimum, 1½ quarts for drinking between meals, 2½ quarts for cooking and for drinking at meals. Two gallons per man should be considered the desirable minimum under adverse conditions. It has been established that there is no such thing as acclimatization to stringent amounts of water. The water requirements of the human body are as absolute as those of a steam locomotive in that water consumption can be reduced only at the sacrifice of energy output. Furthermore, the desire for water rises sharply during periods of nervous strain. When under fire or in actual combat men consume large quantities of water. If pure water, or the means of purification are not available the danger of drinking contaminated water is greatly increased during such periods. Thus the provision of an abundant supply is a positive measure in the prevention of water-borne disease.

The per capita daily consumption of potable water under various conditions is, therefore, about as follows:

	Gallons
Permanent stations. Abundant supply for all ordinary uses	100
Advanced bases, well established. Adequate supply for domestic type uses	50
Advanced bases, newly established. Minimum supply for all uses	25
Temporary camps and advanced bases during construction. Water for drinking, cooking and washing. Little if any for bathing and laundry	5
Combat conditions. Desirable minimum for drinking and cooking only	2
Combat conditions. Absolute minimum for drinking and cooking	1

Occasionally it may be necessary to provide water for animals and vehicles from the potable supply. The following daily consumption figures may be useful in such cases:

	Gallons
Horse	10
Mule or donkey	6
All draft animals, absolute minimum	3
Car, truck or other water cooled engine. Normal	0.1
Car, truck or other water cooled engine. Desert	0.5

Essential Phases of Water Santitation.—Water sanitation measures may be divided into the following categories:

1. Selection of raw water source of good quality and one which is subject to reasonable protection from severe contamination.

2. Design of supply and distribution works to exclude contamination by eliminating all connections or openings through which non-potable water might be pumped, sucked, diverted or flooded into the potable water system.

3. Provision of adequate and well-designed and maintained water purification facilities.

4. Maintenance of proper operating and laboratory control of purification processes.

5. Proper sterilization of all new pipe lines and equipment and of all lines that have been opened for repair or alteration.

6. Routine analytical checks on the potability of water to discover sanitary defects supplemented by prompt and positive corrective action when indicated.

7. Periodic inspections of sources, facilities and practices to assure the effectiveness of water sanitation.

Failure to properly carry out any of the above measures may permit sooner or later the occurrence of that unfortunate combination of circumstances which produce water-borne epidemics.

Responsibility for Water Supply.—The Commanding Officer is responsible for all phases of water supply. In continental shore stations he is assisted by the Public Works Officer and the Medical Officer. The Public Works Officer is responsible for the design, construction, operation, maintenance and administrative supervision of the water works. The Medical Officer assisted by his Sanitation Officer has the responsibility of advising when any phase of water sanitation is unsatisfactory and of recommending corrective measures. Under normal conditions adequate protection of water quality can be obtained through cooperation of the Medical Officer and the Public Works Officer. It is wise, however, to confirm recommendations and actions in written communications to the Commanding Officer. If the situation demands it, a letter to the Bureau of Medicine and Surgery via official channels should produce a solution at the District of Bureau level. The Quarterly Sanitary Report is appropriate for recommendations that are not of immediate urgency.

The Medical Officer's responsibility for water supply in the field and on advanced bases varies greatly with the situation. During the initial phase of amphibious operations each unit may carry in its own water or may depend on local supplies sterilized in lyster bags and canteens. The responsibility for the adequacy and purity of the water under these conditions falls largely on the unit Medical Officers. They must take part in initial plans for operations and arrangements for supplies and must indoctrinate all hands in the fundamentals of water sanitation. The unit commander will depend heavily upon his medical officer to locate sources of water and supervise its treatment and distribution. When filtration or distillation equipment has been brought in by the Marine Engineers or by the Construction Battalions, the responsibility for water treatment shifts to these organizations, thus reducing the need for such close supervision by the Medical Officers or their representatives. Later on when the Advanced Base has been well established, the normal division of responsibility between the Public Works or Engineer Officer and the Medical Officer develops.

Satisfactory water sanitation in the field rests almost entirely on thorough planning and preparation. All unanticipated problems must be solved on the spot. A report of difficulties or failures may, however, lead to improvements in preparations for later operations.

NATURAL WATER SOURCES

Types of Water Sources.—The types of natural water are: (1) rainwater, (2) surface water, (3) ground water and (4) sea water.

Rainwater.—Rainwater resembles distilled water in quality. Its freedom from minerals (softness) makes it an excellent water for cooking, bathing and for laundries and boilers. However, it lacks palatability and is aggressive or corrosive because of the absence of minerals. Rainwater contains dissolved gases as well as dust particles and bacteria swept from the air. As a source, rainwater is important only on small islands or in isolated places where ground water is salty and surface water inadequate. Under these conditions, where the requirements are small and precipitation heavy, rain may furnish an adequate supply for all uses. In many places it will prove valuable in augmenting the supplies from other sources.

Rainwater is collected from the usual type impervious surfaces such as roofs, concrete pavements and barren rocks or from areas rendered impervious by spreading tarpaulins or galvanized sheet metal. The volume derived depends on the catchment area and on the amount of rainfall. The volume in gallons that may be recoyered from an impervious surface equals the horizontal area in square feet multiplied by one-half the rainfall in inches. In order to make this amount of water available storage must be provided to hold water for use during the periods between rains. If precipitation is uniformly distributed throughout the year, storage equal to the average monthly rainfall should be sufficient. If there is an annual wet season, with little or no rain during the intervening months, the gallons storage needed to fully utilize rainwater will equal the horizontal catchment area in square feet multiplied by one-half the annual rainfall in inches multiplied by one-twelfth the length of the dry season in months. Rainwater may be stored either above or below ground in any convenient tank or container. Evaporation will be reduced and

the water kept cooler and thus more palatable if stored in underground cisterns. Storage receptacles should be protected from dust and dirt, and from contamination by polluted surface or ground water. They should be covered or screened to prevent mosquito breeding or the entrance of vermin.

The surfaces from which rain is collected are usually subject to contamination by birds, animals and dust, and if at ground level perhaps by human wastes. The first rain which falls during a storm flushes these substances from the surface so should be wasted. Rainwater should be chlorinated unless it can be demonstrated that there is no chance of contamination during collection and storage.

Ground Water.—Water in the interstices of saturated earth and rock is known as ground water. The water table is the upper level of the zone of saturation or the level at which water stands in wells. The ground water body is fed by infiltration of rain and melting snow and is depleted by flow from springs, withdrawals from wells and by seepage into swamps and streams. No more water can be continuously taken from the ground than enters by infiltration from the surface. The rate of lateral movement through the ground and thus the rate of withdrawal from the wells is governed by the porosity of the earth Large yields of ground water are obtained from properly constructed wells penetrating beds of gravel and coarse sand or creviced and cavernous rock Wells in clay or dense unfractured rock yield little water Artesian waters rise from porous strata overlain by confining beds of impervious clay or rock.

Fresh ground water on volcanic or coral islands usually occurs as a lense floating on the salt water. The flushing action of fresh accretions of rainwater from the surface and the elevation of the water table above sea level holds back the salty water. The recovery of this water is best accomplished by means of wells dug on high ground near the center of the island. If possible the water should be removed at low tide by a skimming process which will prevent lowering the water table sufficiently to pull salt water up from below. Brakish water is sure to appear in these wells if the level is drawn down to or below sea level for any considerable period of time.

The quality of ground water is determined by the environment through which the water passes. The normal percolation processes filter out suspended matter and bacteria. Bacterial activity in the soil removes organic matter and replaces the oxygen with carbon dioxide generated by decomposition. The carbon dioxide renders the water aggressive and in the presence of limestone, coral or other soluble rock the mineral content of ground water may rise to high levels. In areas where cavernous limestone or volcanic rock are near the surface, water may enter through sinkholes, fissures and other openings. This water retains the objectionable characteristics of surface water such as high turbidity and bacteria content and its character is little improved by movement through open passages in the rock. The presence of free flowing channels in the ground or a rise in turbidity of ground water following rains are danger signals.

All wells are sooner or later subject to pollution either through flow in open formations in the ground, by leakage from the surface down outside the casing or through perforations in the casing as corrosion progresses. Well water should therefore be adequately chlorinated.

Surface Water.—Surface water supplies are obtained from rivers, streams, lakes, ponds and pools. Since the amount and quality of water available from a surface source will vary widely as the season changes, it may be necessary to investigate the history and habits of a stream or lake before placing too much dependence on it. Elaborate hydrological studies precede the choice of the source for a large supply. In the field there is neither time nor need for such studies.

Surface sources are supplied by run-off following storms and by the flow or seepage of water from the ground. During rainy weather streams are turbid and polluted with material washed from the ground surface. Due to the rapid movement and interference with natural purifying processes during floods sewage and other contamination may be carried for long distances. Dry weather flow consists primarily of ground water so streams are clear and more highly mineralized during dry periods. Self purification processes are most active in a clear stream and though the dilution of sewage and other wastes is reduced during dry weather, the recovery of stream purity may take place in a relatively shorter stretch of channel. A normally sluggish stream is high in organic matter and may be

odorous due to dense algae growths and the formation of sludge banks. Such streams are poor sources for a water supply. Mountain streams and lakes remote from inhabited area are usually clear and contain water of excellent quality.

Surface water must always be sterilized and should receive such additional treatment as the situation permits to render it free of turbidity, tastes and odors. In areas where amoebiasis and schistosomiasis are prevalent all water should be filtered or where this is impossible should either be boiled or disinfected by super-chlorination, or by other chemical processes known to destroy amoebic cysts. Surface waters subject to contamination by chemical warfare agents must be examined for the presence of these substances and avoided or purified as the situation demands.

Sea Water.—The sea serves as the major source of water for the fleet. Ashore it is utilized only in the absence of adequate fresh water sources. Sea water contains up to 37000 parts per million of dissolved salts which must be removed by distillation. Since shallow coastal waters may carry considerable organic material and turbidity or be polluted with oil or other wastes it is usually desirable to filter sea water before pumping it to stills located on the beaches. Advantage may be taken of natural filtration and the diluting effect of ground water by distilling water withdrawn from shallow wells located along the shore. Since distillation is an expensive process all available fresh water sources should be fully utilized as soon as the military situation permits.

Selection of Source.—The choice of a water source is influenced by quantity, quality, ease of procurement, ease of purification and by other factors. Supplies for permanent shore stations are usually selected on the basis of detailed engineering studies of all reasonably promising sources. However, during military operations, a hasty estimate of quality and adequacy of a source may be all that is possible. A water reconnaissance is usually made to find and look over available sources and to select that which appears most suitable.

The considerations of quality which merit study are:

1. Freedom from contamination by sewage or other wastes and from enemy pollution with chemical agents or bacteria.

2. Freedom from turbidity, color, and taste.

3. Freedom from excessive amounts of organic and mineral substances.

There is a tendency based probably on recreational experience, to locate military camps along stream banks or close to shore even though the health hazards may be much greater in these areas than on high and dry ground not far distant. In planning camps and bases in the tropics too much importance ought not be given to the convenience of locating near a source of water. The effort required to pipe or haul water to healthier sites may be insignificant when compared with the difficulty and expense of controlling insects in the swampy areas along a water course.

WATER FROM MUNICIPAL SOURCES

Quality of Municipal Water.—Hygienically pure and esthetically pleasing water is supplied in practically all communities having public water supply systems. Water consumers have grown to expect a palatable as well as a safe water and are ready with complaints whenever water has a slightly unpleasant taste. With few exceptions, municipal supplies in the United States are palatable and meet the quality standards of the United States Public Service. This situation does not prevail widely outside the United States. All water supplied from public systems abroad should be considered of doubtful quality and should be tested and if necessary sterilized.

Responsibility of the City.—When municipal water is purchased for a Naval Station the city is under legal obligation to deliver water that is pure and safe from possible contamination. The city is not obliged, however, to deliver water containing residual sterilizing agent. If free chlorine is used to disinfect water at the purification plant, maintenance of residuals at distant points in the system may be impossible without so charging the water with chlorine that it would be unfit for use in areas near the point of chlorination. When the ammonia-chlorine process is used, residual action may be maintained more easily.

The city is responsible for protecting the purity of water throughout its distribution system. It is well recognized that cross-connections with polluted supplies constitute a danger to the health

of the community. Police power regulations are, therefore, in force almost everywhere forbidding or controlling such cross-connections and giving representatives of the municipality the right to inspect points of possible cross-connections on the consumers' property and the right to discontinue the public supply when improper cross-connections are found.

In order to assure the safety of the water the city or other water supply agency must sample and test the water with reasonable frequency at points distributed throughout the system, and on request must supply the results of these analyses to consumers. The city's water works system and its operating practices are normally open to inspection and review.

Responsibilities of the Navy.—The Navy is responsible for the protection of the purity of water during distribution on its premises. It is further obligated to permit periodic inspections by representatives of the water supply agency charged with protecting the public supply. The Navy is entitled to demand delivery to its premises of a pure, wholesome and safe water and should carry out laboratory tests of water at the point of delivery when there is question as to the quality of water purchased.

ANALYSES AND STANDARDS

Water Analyses and Standards.—The term "safety" as applied to potable water indicates the degree of reliability of the measures used to assure a supply uniformly high in quality. The safety of a supply depends on the protection of the source; the purification processes used and the excellence of their design and operation; the proper design, construction, maintenance and operation of pumping stations, reservoirs and distribution systems; and on the absence of cross-connection or other means whereby non-potable water may enter the system. The safety of a water supply is judged by (a) periodic sanitary surveys of all physical features of a water system and an investigation of operating and maintenance practices; and (b) routine laboratory analyses of water quality.

Two types of quality standards are used in water sanitation practice: (a) standards for certifying public supplies on the basis of numerous past laboratory analyses and (b) standards for judging the current safety of a supply from the individual test results.

The bacteriological examinations recognized as of most value are:

(a) The count of total colonies developing on agar or gelatin in 48 hours at 20° C.

(b) The count of total colonies developing on agar in 24 hours at 37° C.

(c) The quantitative estimation of organisms of the coliform group.

Of these the test for the coliform group is the most significant because it affords the most nearly specific test for the presence of fecal contamination. Only this test is included in the bacteriological standards recommended by the United States Public Health Service. Plate counts, when regularly made, are useful in controlling water purification processes and in determining the current safety of a water supply.

The standards adopted by the U. S. Public Health Service, September 25, 1942, for drinking and culinary water supplied by common carriers in interstate commerce are used throughout the United States for certification of water supplies and for judging the past performance of sanitation measures. The numerical values specified in the Public Health Service Standards are such that communities with reasonably safe supplies can qualify to furnish water for common carriers. In preparing these standards it was reasoned that persons from such communities are entitled to be served, while on interstate travel, water equal in quality to that which they receive at home. A lack of understanding of the background and purpose of the Public Health Service Standards has led to some criticism, particularly when an attempt is made to use these standards for judging the significance of individual test results.

The U. S. Public Health Service Standards are reproduced here with slight modification for the sake of brevity and clarity. Standards appearing herein should be looked upon as a guide to Naval sanitation practice, but shall not be considered as official Navy standards. Water is procured and used under such wide variety of circumstances in the Naval service that no single set of standards can be designed to fit all situations. The policy of the Navy is to forbid consumption of any water

that might detrimentally affect the health and efficiency of personnel. Since the presence of pathogenic organisms can normally be demonstrated only by consumption of the water a variety of analytical and survey technics that provide circumstantial evidence must be used for judging the safeness of a water.

Standard as to Source and Protection.—The water supply shall be obtained from a source free of pollution or shall be adequately protected by artificial treatment. The water supply system in all its parts shall be free from sanitary defects and health hazards and shall be maintained at all times in a proper sanitary condition.

Bacteriological Standards.—The U. S. Public Health Service standards for certification of supplies are based on standard samples made up of five standard portions. Standard portions may be either ten milliliters (10 ml) or one hundred milliliters (100 ml). The bacteriological quality shall be in accordance with 1 and 2 when ten milliliter (10 ml) portions are used and in accordance with 3 and 4 when one hundred milliliters (100 ml) are used.

1. Of all the standard ten milliliter (10 ml) portions examined per month in accordance with the specified procedure, not more than ten (10) per cent shall show the presence of the coliform group.

2. Occasionally three (3) or more of the five (5) equal ten milliliter (10 ml) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

a. Five (5) per cent of the standard samples when twenty (20) samples have been examined per month.

b. One (1) standard sample when less than twenty (20) samples have been examined per month.

Provided further that when three or more of the five ten milliliter (10 ml) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the sampling point shall be examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

3. Of all the standard one hundred (100 ml) portions examined per month in accordance with specified procedure, not more than sixty (60) per cent shall show the presence of organisms of the coliform group.

4. Occasionally all of the five (5) equal one hundred milliliter (100 ml) portions constituting a single standard sample may show the presence of organisms of the coliform group, provided that this shall not be allowable if it occurs in consecutive samples or in more than

a. Twenty (20) per cent of the standard samples when five (5) or more samples have been examined per month.

b. One (1) standard sample when less than five (5) samples have been examined per month.

Provided further that when all five of the standard one hundred milliliter (100 ml) portions constituting a single standard sample show the presence of organisms of the coliform group, daily samples from the same point shall be examined until the results obtained from at least two consecutive samples show the water to be of satisfactory quality.

These standards may be interpreted as simply implying that the mean density of organisms of the coliform group shall not exceed about 1 per 100 ml. The rather complex wording of the standards results from the need for taking into account two facts (a) that according to the laws of chance a density of 1 per 100 ml may be exceeded in a small proportion of the samples tested even though the mean density is actually 1 per 100 ml, and (b) that variations exceeding certain amounts with various frequencies indicate potential danger even though the average quality of the water over a period of time may be satisfactory.

There are no widely accepted standards for judging the current safety of a water supply from individual test results. Unfortunately the difficulty in judging the significance of a single bad sample and in deciding what should be done about it is so great that no uniform rules can be developed. Nevertheless, one of the most important reasons for testing water is for determining from day to day whether sanitation measures are functioning properly. Efficient filtration and chlorination should yield a water free from "presumptive coli." If a

single positive tube occasionally appears in the five comprising a standard sample no action would be indicated other than a check to see that chlorine residuals had been continuously adequate. However, if several tubes were positive or if single positives appeared frequently chlorination should be stepped up, or if chlorination had been satisfactory, a search should be made for the source of trouble. A majority of positive tubes in consecutive samples would normally indicate a sufficiently serious breakdown in water sanitation to justify a careful investigation of the condition of the system, the water meanwhile being regarded as unsuitable for use unless boiled.

Well operated purification plants produce water with a 24 hr. 37° C. plate count averaging between 2 and 10 colonies per ml. and rarely exceeding 50 per ml. Plate counts exceeding a reasonable maximum require explanation. A limit of 200 colonies per ml. is often used. Plate counts running into thousands of colonies per ml. in water that has been chlorinated almost always indicate sanitary defects even though tests for the coli-aerogenes group are negative.

Experience suggests that no serious hardship is imposed by regarding a positive presumptive coliform test, without further differentiation, as an index of fecal contamination. Laboratory technics are simplified and a higher standard of safety attained where this practice is followed. In any event the appearance of gas in the presumptive test is a sign of undesirable possibilities.

Physical Standards.—Water should have a turbidity less than 10 ppm (silica scale) a color less than 20 (standard cobalt scale) and should be free of objectionable tastes and odors.

Chemical Standards.—The chemical quality will ordinarily be satisfactory if the water satisfies the bacteriological and physical standards and the chemical standards that lead (Pb) not exceed 0.1 ppm and fluoride not exceed 1 ppm. Salts of cadmium, arsenic, selenium, barium, hexavalent chromium, heavy metal glucosides or other substances with deleterious physiological effects should not be allowed in the water supply system. Ordinarily analysis for these substances need be made only semi-annually. If, however, there is some presumption of unfitness because of these elements periodic determinations for the element in question should be made more frequently. The following chemical substances should not occur in excess of the following concentrations:

Lead (Pb)	0.1 ppm
Fluoride (F)	1.0 ppm
Copper (cu)	0.2 ppm *
Iron (Fe) and Manganese (Mn)	0.3 ppm
Magnesium (Mg)	125 ppm
Zinc (Zn)	15 ppm
Chloride (Cl)	250 ppm
Sulphate (SO_4)	250 ppm
Phenolic compounds	0.001 ppm
Total solids	1000 ppm
Total solids preferable limit	500 ppm

Since the significance of these limits is different for the various chemicals, judgment must be used in their application. For example, the permissible limit of lead should not be exceeded in any supply used for considerable periods of time by the same individuals. On the other hand, iron and manganese contents greatly in excess of the stated limit will result only in undesirable laundry, vegetable, and plumbing fixture stains. Permissible limits of chemicals in water to be used for high pressure boiler feed will be much lower than those stated above.

Methods of Analysis.—The analyses used to determine the bacteriological, physical and chemical characteristics of water shall be made in accordance with the Standard Methods for the Examination of Water and Sewage, American Public Health Association, or (in cases not covered) in accordance with the Official and Tentative Methods of Analysis, Association of Official Agricultural Chemists.

Sampling for Bacteriological Analyses.—1. The frequency of sampling and the location of sampling points on the distribution system should be governed by the local situation. When difficulty with water sanitation is experienced or is anticipated the frequency of sampling should be increased. The desirable minimum water samples for bacteriological test on continental shore stations is one per week for all stations having complement of less than 5,000 men and about one per week for each 5,000 men in larger activities. Samples should be collected at the place where purified water enters the system

* The new USPHS limit for copper is 3.0 ppm. There is evidence that this limit may be higher than should be permitted in drinking water used aboard naval vessels. Adherence to the old USPHS limit of 0.2 ppm is conservative.

and at points on the distribution system selected to produce the maximum information concerning the cause of any abnormalities in water quality.

2. Samples must be collected aseptically and if the water contains residual chlorine, in sodium thiosulphate treated bottles.

3. It is difficult to obtain samples from an ordinary spigot without the water being contaminated by leakage around the turnoff stem or by bacteria on the lip of the faucet. The most satisfactory method of sterilizing the spigot is by the liberal use of a blow torch. In filter plants and laboratories special sampling outlets are sometimes provided from which a small stream is allowed to run continuously. In collecting samples from open tanks or reservoirs a swinging motion of the arm should be used to prevent any water which may have touched the hands from entering the bottle. Samples should be promptly transported to the laboratory and if possible planted immediately upon arrival. If water samples must be shipped or stored they should be properly refrigerated.

Laboratories.—Epidemiological Control Units are equipped with full laboratory facilities for the bacteriological analysis of water. Their services are available to all activities within the major commands to which they are assigned. Some of the laboratories maintained by the Bureau of Yards and Docks for the control of filter plant operation are equipped for bacteriological analyses. In the absence of conveniently located naval water laboratories advantage should be taken of the bacteriological facilities in naval hospitals or the services of state-operated laboratories enlisted.

DETECTION OF CHEMICAL WARFARE AGENTS

Responsibilities.—In the few instances where contamination of water supplies with chemical agents has been encountered casualties have been high. It is therefore important to test water for chemical warfare agents whenever there is any reason to suspect their presence. The Medical Officer is responsible for making these tests and if an uncontaminated source cannot be found the group responsible for procurement must decontaminate the water.

Toxic Limits.—The toxic limit for lewisite is 10 ppm as As_2O, provided the water is chlorinated by the standard procedure for bacterial purification and is used for not more than one week. Nitrogen mustards in concentrations of 10 ppm have produced vomiting in man but have not caused actual casualties. In higher concentrations they are extremely toxic. Mustard dissolves slowly in water but may be found floating in tiny globules, as a film on the surface or collected in pools on the bottom. The limits for cyanogen chloride and cyanide are 10 ppm.

Reactions With Water.—The three vesicants—lewisite, mustard, and nitrogen mustards—all react with water to form hydrochloric acid and the hydrolysis product corresponding to the agent. Lewisite reacts with water practically instantaneously, forming the hydrolysis product "lewisite oxide," which is toxic and somewhat vesicant. Mustard reacts with water to form the nontoxic thiodiglycol. A solution containing 100 ppm mustard becomes nontoxic at the end of one hour. Some types of mustard contain a highly odorous compound which renders the water non-palatable even after hydrolysis. Nitrogen mustards hydrolyze slowly to a nontoxic product. A solution containing 100 ppm may remain toxic for four to six days. Cyanogen chloride, cyanide, and heavy metal salts dissolve in water but do not react extensively with it.

Water Testing Kit.—For the sake of simplicity, analytical procedures have been developed to employ dry reagents which are furnished as tablets or pellets of proper size. Except for warming with the hand in some of the tests, no heat is required. The reagents and equipment are packed in a pocket-sized transparent plastic container, approximately 5½" x 3¾" x 1¾", which is divided into 10 compartments and contains equipment for testing 15 samples of water.

Application of Water Testing Kit.—The primary purpose of the kit is to detect contamination by chemical warfare agents in the raw water. The limits of the sensitivity of the tests are on the safe side.

If none of the tests indicates amounts of chemical agents in the raw water beyond the specified toxic limits, the water can be used after usual treatment at water points or in Lyster bags without any specific decontamination procedure for chemical agents.

Under most conditions a positive result for any of the tests included in this kit will indicate probable contamination in which event the water should not be used until a complete analysis can be made. More complete testing equipment is required for the quantitative determination of contaminants. Such quantitative tests are under the cognizance of the group responsible for the procurement and treatment of water.

Sensitivity and Limitations of the Tests.—If the tests are carefully performed, the threat of serious casualties from contamination of the water with known agents will be avoided.

The arsenic test will show whether any arsenic is present or not. The lengths of stain produced by 5, 10, and 15 ppm of arsenic in the form of organic arsenicals are sufficiently different so that one can tell approximately how much arsenic is present. Inorganic arsenite or arsenate produces very long, dark stains at the above concentrations.

The pH test is a general screening test. Any water with a pH below 6.5 or above 8.5 should be suspected of contamination.

The test for mustards will detect mustard or the nitrogen mustards in 5 ppm. Thiodiglycol will not react. Ethyl iodoacetate and chloroacetophenone will also react, but these can be detected readily by their odor so it is thought they will cause no difficulty. Cyanogen chloride yields a yellow color with the RA tablets alone and can be detected as low as 10 ppm. No blue color develops when the RB tablet is added.

The ortho-tolidine reaction used to detect chlorine residuals in the chlorine demand test is sensitive to 0.1 ppm of chlorine. A chlorine residual does not mean a safe water. It has been shown that water contaminated with mustard or thiodiglycol may show a chlorine residual and actually still have a chlorine demand. An excess of 4 to 5 ppm of chlorine above what is needed for the actual chlorine demand is necessary in order to have complete reaction between the chlorinating agent and the mustard or thiodiglycol. If this condition is not met, the water will show a chlorine residual as determined by the ortho-tolidine reaction when it still has a chlorine demand. Other colors may be obtained when using the ortho-tolidine reaction. If the color is blue or green, it means there is too much ortho-tolidine for the amount of chlorine present. A red or orange color means that too great an amount of chlorine has been added.

Interpretations, Limitations of Tests.—Negative results from all of the tests indicate that the water is safe for use after chlorination insofar as chemical warfare agents are concerned. A positive result for any one of the tests is presumptive evidence that the water is contaminated with a chemical warfare agent. Water showing a positive result for any one of the tests shall not be used without special treatment to remove the chemical warfare agent except in cases where it can be clearly demonstrated that one or more of the limitations specified below is applicable.

The test for arsenic allows some latitude in the interpretation of the results. If the stain on the test is not longer than ¼ inch, the arsenic content is not more than 10 ppm. as organic arsenic. Water with this concentration of organic arsenic may be used for a period not to exceed 1 week because of possible cumulative effects, provided all the other tests are negative and the water is thoroughly chlorinated. If the stain is longer than ¼ inch the water shall not be used.

A pH below 6.5 should be regarded with suspicion unless the character of the water source seems to indicate a naturally low pH. Contamination of the water by mustard, the nitrogen mustards, or arsenicals would lower the pH as all these chemical agents release hydrochloric acid in water solution. A pH above 8.5 probably means contamination with some basic material as potassium cyanide.

If the test for mustard and the nitrogen mustards is positive, the water should be rejected for all purposes. Water may pass the test for nitrogen mustards and still give symptoms if consumed in large quantities. Hence, the water should not be used without special purification if even the faintest blue color develops. When the result of the test is questionable, the amount of water permitted per man, at the first drinking, should be limited to ½ pint; if no symptoms of nausea or vomiting develop during the succeeding 2 hours, the water may be used freely thereafter.

A high chlorine demand means contamination with mustard, thiodiglycol, arsenicals, or pollution by organic waste material. If the arsenic test is negative, the chlorine demand is a measure of contamination by mustard. However the water may

also be contaminated with the nitrogen mustards which do not react in the chlorine demand test.

Action When Water is Contaminated by Chemical Agents.—Contamination discovered in otherwise suitable water should be reported promptly to the commanding officer, so that the matter can be brought to the attention of the officer responsible for decontamination.

The commanding officer will establish the necessary safeguards to prevent men from drinking the contaminated water.

An alternative source of uncontaminated water should be sought, and if found should be employed.

If a source of uncontaminated water cannot be found, consideration should be given to moving to a different location, or to importing purified water.

In any event, the contaminated water should not be used by men until it is decontaminated.

Use of the Kit.—The field kit for water testing is designed as a reconnaissance kit. Its purpose is to screen out sources of water so contaminated with chemical agents that they cannot be rendered potable by customary field treatment methods, such as chlorination in the Lyster bag. Individuals performing the tests must have normal color vision.

Negative tests indicate water suitable for chlorination and may thereafter be used by troops.

Subject to the limitations already listed, if any of the tests are positive, the water should not be used until a more complete analysis can be made.

The main purpose of the kit is to detect contamination by chemical agents in *raw water. It is not designed for use in the testing of treated water.* Chemical reactions during water treatment invalidate the interpretations.

DISINFECTION OF MAINS AND EQUIPMENT

Importance of Disinfection.—All parts of a water collection, purification and distribution system are subject to gross contamination during the period of construction. Pipe, valves and other equipment and materials scattered on the ground or in roadside ditches near the job accumulate surface washings and are often inhabited by small animals. It is common practice for construction personnel to urinate in the trenches or other excavations where equipment is being installed. It is, therefore, necessary to thoroughly flush all newly installed works and to sterilize them with heavily chlorinated water. All underground distribution systems leak to some extent. When the usual internal pressure is maintained this leakage is outward, but when pipes are dewatered for alterations, repair or extension, the possibility of the inward leakage of shallow polluted ground water constitutes a sanitary hazard. Distribution lines that have been dewatered and other parts of the system that have been opened must, therefore, be sterilized before being placed in operation.

Disinfection Procedures.—Sterilization methods should incorporate the following steps:

1. Thorough flushing with potable water.

2. Exposure of all internal surfaces of equipment to water containing at least 50 ppm of free chlorine for a contact period of 4 hours or more, or to water containing at least 100 ppm of free chlorine for one hour or more.

3. After the required period of contact, reflushing with potable water until the chlorine residual falls to 1 ppm or less.

The lines or equipment will then be ready for use. Bacterial counts should receive attention until it is evident that sterilization has been adequate and other difficulties avoided.

Disinfecting Agents.—Free chlorine, purchased in the form of a gas, a compound or a solution is the only satisfactory chemical for sterilization of water works. Grade A hypochlorite (HTH or Perchloron) is the most satisfactory as well as the most readily available form for general use. It dissolves easily and contains 65 to 70 per cent available free chlorine. One pound in 800 gallons or in 100 cubic feet of water gives a chlorine dose of about 100 ppm. Calcium hypochlorite (chloride of lime) is less easily used and contains only about one-half as much available chlorine per unit weight of compound. Commercial prepared sodium hypochlorite solutions (chlorox, zonite etc.) may be obtained in 5 and 10 per cent strengths. One gallon of 10 per cent solution added to each 1000 gallons of water will give about 100 ppm free chlorine. All hypochlorites raise the pH of water and thus reduce the effectiveness of the chlorine. This may be of considerable importance if chlori-

nation raises the pH of the water above a value of 8. If chlorine gas is used to disinfect mains or equipment, a chlorine feeding device in the hands of a competent operator is required.

Disinfection of Wells.—Wells should be disinfected after construction, cleaning or removal of equipment for repair. When the well equipment is ready for operation the well should be flushed by pumping to waste until the water is free of turbidity. A dug well may then be sterilized by pouring in the calculated amount of chemical either in powdered form as as a concentrated solution. Water in the well should be agitated to distribute the chlorine. To overcome the difficulty of mixing the chemical with the water in a drilled well, a volume of 100 ppm solution some 50 per cent greater than the quantity of water standing in the hole should be made up in tanks and run down between the riser pipe and the casing.

Disinfection of Water Mains.—Careful planning and attention to detail is required in order to properly flush and sterilize underground water pipes. When an entire system must be sterilized, best results are obtained by isolating and treating consecutive portions of such size that a thorough job may be done with available equipment. The procedure for sterilizing old mains that have been dewatered for repair, alteration or extension is identical with that used for sterilizing parts of a new system. This procedure should be essentially as described in the following three paragraphs.

Flush the portion of the system to be chlorinated in such a way that velocities of six or more feet per second are maintained in each pipe until water flows perfectly clear. Care must be taken to avoid: (a) valve manipulations which allow water to flow from unsterilized into sterilized portions of the system; and, (b) flushing in such a manner that dirt and other material which should be removed is merely carried from one place to another within the system.

After thorough flushing, the portion of the system to be sterilized is closed off and filled with highly chlorinated water. To accomplish this, water from a hydrant on the sterile system outside the part closed off is chlorinated and fed back through a hydrant on the closed portion. If possible this feed back should be to a previously sterilized line included in the closed portion. This overlapping assures sterilization of all parts of the system. The above ground, hydrant to hydrant connection can be avoided by adding chlorine through a tap just upstream from a gate valve selected for admitting water to the closed system. When chlorinating equipment is in operation and the cross-connected hydrants or the water-admitting valves have been opened, chlorinated water is drawn into the closed system by bleeding each hydrant and other outlet until water having a strong chlorine odor appears. If the chlorinating apparatus is set for constant feed, the dosage in ppm will vary inversely with the rate of bleeding from the closed system. Therefore, it is desirable to set the chlorinator to give a dosage rate of 50 to 100 ppm or more when water flows from a single full opened outlet and to bleed one outlet at a time progressively away from the point of chlorination. For accurate control of dosage a water meter must be used either at the point of bleeding or on the feed line.

Flushing after chlorination presents no problem. Poor flushing will be evidenced by complaints of chlorine odor and taste. If possible chlorinated water from a part of the system that has just been sterilized should be used to flush out the next part to be treated thus conserving water and using the sterilizing effect of the remaining chlorine.

Disinfection of Equipment.—All equipment including pumps, filters, filter regulating equipment, piping, etc. must be thoroughly flushed and sterilized. Since the procedure to use depends on the physical arrangement of the equipment in each particular case, it is not possible to formulate rules that would apply to all situations. The principles outlined under Disinfection Procedures should be followed.

Disinfection of Pure Water Reservoirs and Tanks.—It will frequently be impractical to sterilize a large reservoir or tank by filling it with highly chlorinated water. In such cases the tank or reservoir should be flushed or washed down with a strong hose stream and sterilized by swabbing all internal surfaces with a solution containing at least 200 ppm free chlorine.

WATER PURIFICATION—ESTABLISHED BASES

Types of Water Purification Plants.—Water is purified on established bases either by simple chlorination or by treatment in a modern filter plant.

Simple chlorination is suitable for purification or protection of purchased municipal supplies that may at times be questionable in quality, and for disinfecting clear and relatively high quality water from wells or from mountain streams or reservoirs. Chlorination alone should be used on permanent stations only when the raw water is normally of very good quality. It then provides a safety factor against chance contamination and against breakdown in measures used to protect the source. When the raw water is normally unfit to drink a filter plant should be provided. The ordinary purification plant includes means for coagulating, settling, filtering and disinfecting water. In special cases additional processes for softening and demineralization may be required.

Raw Water Quality.—In order for purification plants to produce continuously satisfactory water the raw water pollution must remain within reasonable limits. For plants which provide coagulation, sedimentation, filtration and disinfection the coliform bacteria in the raw water should not average more than 5,000 per 100 ml in any month and should not exceed this number in more than twenty (20) per cent of the samples examined in any month. Waters showing numbers exceeding 5000 per 100 ml in more than twenty (20) per cent of the samples and not exceeding 20,000 per 100 ml in more than five (5) per cent of samples examined during any month require auxiliary treatment. By auxiliary treatment is meant presedimentation or prechlorination, or their equivalents, either separately or combined as may be necessary. Waters containing coliform organisms in excess of 20,000 per ml in more than five (5) per cent of the samples examined in any month should be considered as unsuitable for use as a source of water supply unless they can be brought into conformance with the above requirements by prolonged preliminary storage or some other measure of equal permanence and reliability.

In addition to meeting bacterial requirements, the raw water should not contain any toxic or harmful substances, or organisms not readily removed by ordinary water treatment. Raw water should be free of excessive amounts of acid, microscopic organisms or organic matters that might interfere with the normal operation and efficiency of water treatment processes.

Plant Capacity.—The filter plant should have a capacity at least 50 per cent in excess of the average daily draft.

Coagulation and Sedimentation.—The great importance of the coagulation and sedimentation process in a modern water treatment plant is not often fully appreciated. This process normally accomplishes at least 70 or 80 per cent of the purification and in well designed and operated plants may remove well over 90 per cent of the bacteria and suspended matter. The coagulation and sedimentation process has an importance beyond the removal of suspended matter. It is a necessary adjunct to rapid sand filtration. The efficiency of filtration and freedom from filter difficulties depends largely on the degree of clarification obtained in the sedimentation process.

Coagulation and sedimentation consists of the following steps:

1. Addition of a chemical which reacts with the alkaline constituents in a water to form a gelatinous precipitate (floc) which entraps particles of suspended water.

2. Rapid mixing (flask mixing) for a period of 1 to 5 minutes to distribute the coagulant through the water.

3. Slow mixing (flocculation) for about 20 to 30 minutes to permit the floc to grow and to entrain suspended matter and bacteria.

4. Passage through large tanks (sedimentation) where the floc is permitted to settle. The detention period in continuous flow tanks should never be less than two hours, and preferably should be six hours or longer.

The chemicals suitable for coagulation of water are: aluminum sulphate (filter alum), $Al_2(SO_4)3 18 H_2O$; ferrous sulphate (copperas), $FeSO_4$; ferric sulphate $Fe_2 (SO_4)$; ferric chloride, $FeCl_3$; ammonium alum (war alum), $Al_2(SO_4)_3.(NH_4)_2 SO_4.24 H_2O$; and sodium aluminate, $Na_2Al_2O_4$. Of these, aluminum sulfate is by far the most widely used. The dosage of alum needed to properly coagulate water usually lies between one-half (½) and two (2) grains per gallon.* Polluted waters may at times require treatment with high doses, 4 grains per gallon or more. Each grain per gallon of alum

* 1 grain per gallon = 17.1 ppm = 143 lbs per million gal.

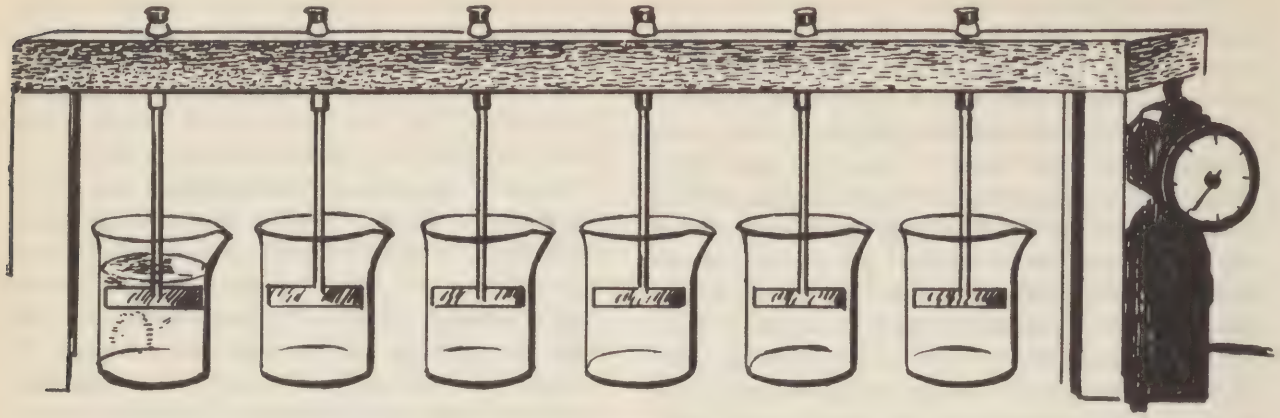


Figure 48.—Multiple mixing device.

theoretically requires about one-half grain per gallon of alkalinity to precipitate the aluminum hydroxide floc. If the natural alkalinity is insufficient, lime or soda ash may be fed.

The correct dose of chemical to use for the treatment of any water at any time can be determined only by trial and error. In a series of jars, beakers or bottles portions of raw water are treated with various doses of coagulant, and after thorough mixing, the size and rate of settling of the floc, and the clarity of the water are observed. The smallest chemical dose that produces a good floc and complete clarification is the correct one to use in the plant. One-half liter samples are convenient for these so called jar tests. Four milliliters (4 mls) of a solution containing 2.14 grams per liter of filter alum ($Al_2(SO_4)3.18H_2O$) added to a one-half liter sample equals one grain per gallon. Using 4 to 8 samples, trial dosages in increments of one-quarter (¼) or one-eighth (⅛) grain per gallon are obtained by adding multiples of 1 ml or ½ ml of the above alum solution. A mixing device for use in making jar tests is illustrated in Fig. 48.

In processing highly polluted water or those containing materials that impart a strong taste or odor it may be necessary to use additional treatments prior to filtration. The important supplementary treatments involve one or more of the following:

1. aeration,
2. superchlorination followed by dechlorination,
3. ammonia-chlorine process, or
4. the use of activated carbon.

In order to insure continuous operation the flocculation and sedimentation basins should be at least two in number. Sedimentation basins not provided with mechanical sludge removal mechanisms must be drained every 4 to 6 months and the accumulated sludge flushed out with strong hose streams.

Filtration.—Two types of filters are in use, the slow sand filter and the rapid sand filter. Slow sand filters are large beds of sand through which relatively clear raw waters may be passed, without pretreatment, at filtration rates ranging from 2 to 8 million gallons daily per acre of filter surface. The schmutzdecke or dirt layer which accomplishes the filtration is a zoogloea built up by natural processes. Slow sand filters are cleaned by the laborious process of scraping off and washing the top layer of sand. Very few filters of the slow sand type have been constructed in the United States in recent years because of their high initial cost and the cleaning difficulties when the raw water contains considerable turbidity. The advantages of simplicity in design and operation favor the use of slow sand filtration for small permanent supplies at overseas stations.

Municipal type rapid sand filters operate at rates of from 2 to 3 gallons per minute (gpm) per square foot of sand area (125 to 200 million gallons daily per acre). Portable pressure filters used in the field may be operated at rates as high as 6 gpm per square foot. Sand beds are normally 24 to 30 inches in depth. The sand used is fairly uniform and of such size that 10 per cent of it is smaller than 0.3 to 0.6 millimeters in diameter. Bacteria and col-

loidal matter would readily pass sand of this size if it were not for the formation of a coating of aluminum hydroxide floc on and in the surface of the sand bed. Since residual floc carried over from the sedimentation basin serves this purpose, the process of coagulation and sedimentation cannot be dispensed with in a rapid sand filtration plant. There is no need for concern about settling out too much of the floc. Enough will always remain to make the filter function. Improved coagulation and sedimentation invariably reduces filter difficulties.

A rapid sand filter, Fig. 49, is cleaned by backwashing the bed with purified water. Salient design features are controlled by the backwashing process which requires the uniform distribution of large volumes of water beneath the bed and the collection of the dirty water rising out of the sand. During washing, the sand bed expands some 50 per cent and the vibrating grains are suspended in the rising wash water. The scouring action is greatly improved by use of "surface washing". Surface washing is accomplished by high velocity jets issuing from perforated pipes suspended in the filter at such level that they are just beneath the surface of the expanded bed, but hang above the sand after it settles back into place when the back wash is turned off. The following steps are involved in backwashing a filter:

1. Close the influent valve and allow the water to drain down to or below the top of the gutters.

2. Close the effluent valve.

3. Open the drain valve.

4. Open the wash water valve, gradually to prevent dislodgment of the gravel, and when full open, wash the filter until it is cleaned. A 5 to 10 minute wash is usually adequate. If surface wash is provided, it is turned on after the bed is expanded and is shut off before the backwash valve is closed.

5. Close the wash water valve.

6. Close the drain valve.

7. Open the influent valve and when filter box is again filled with water open the effluent valve. The filter is then back in operation.

Most filters are equipped with "filter to waste" (rewash) valves and instructions sometimes call for filtering to waste for a few minutes after backwashing in order to permit the floc layer to form

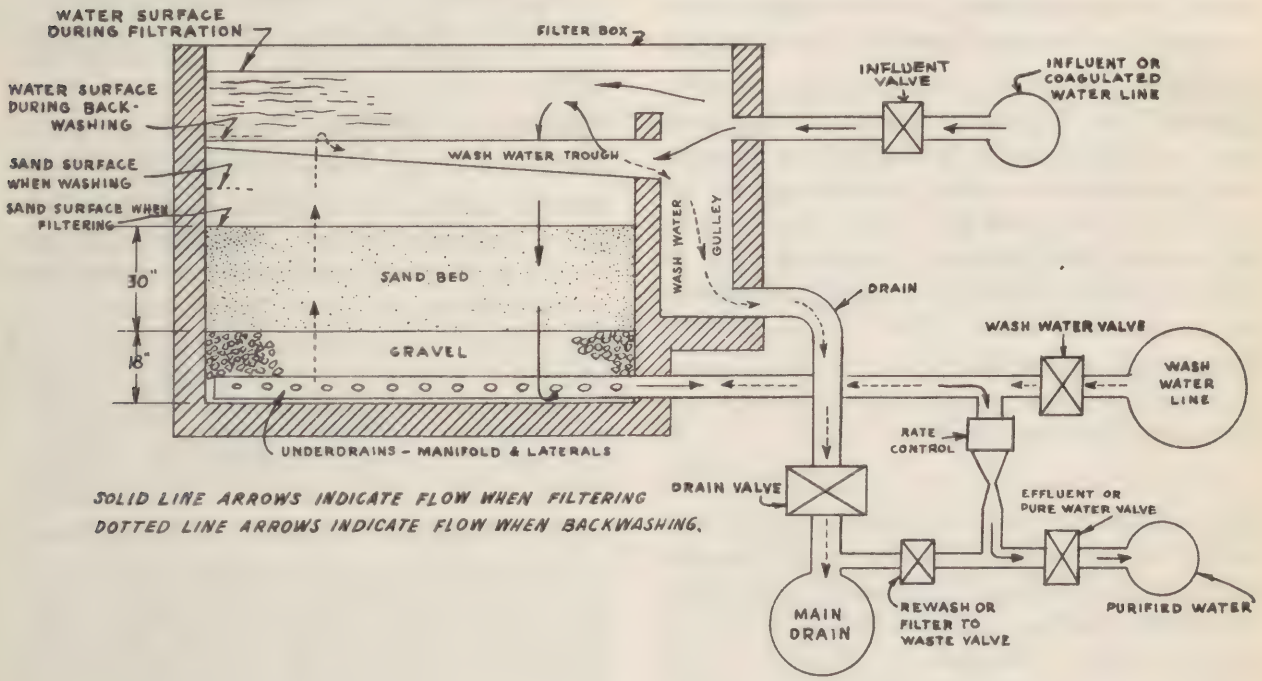


Figure 49.—Cross-section of a rapid sand filter.

on the sand surface and become effective. Filtering to waste has been found to be unnecessary in most plants. Rapid sand filters should be washed when clogged to the point that the filtration rate begins to fall off or when the filtered water begins to show an increase in turbidity. The normal period between washes is 24 to 48 hours. If filters are allowed to operate too long without washing or if the washing process is incomplete filter difficulties are almost certain to develop. The first evidence of trouble will be the appearance of small mud balls on the surface of the sand. These grow in size until they penetrate the bed during washing and form internal accumulations of mud. A condition is soon reached which requires complete removal of sand and gravel for cleaning and regrading. In order to facilitate proper operation and control, efficient loss-of-head gages, rate controllers and other essential control devices should be provided and maintained in good working order.

Filtered Water Storage.—Filtered water is stored in reservoirs called clear wells which are located beneath the filters or near the filter plant. Where located below the filters, adequate protection against leakage of water from other parts of the plant into the reservoirs should be provided. Covered reservoirs located near to, but physically separated from, the plant are preferred. Trap doors and inspection openings should be properly sealed and locked. Suitable vents, protected against outside contamination and screened to exclude insects and rodents should be provided. Filtered water reservoirs should be thoroughly tight against external leakage, should be situated above the ground water table and preferably should have no walls in common with any other plant units containing water in the process of treatment.

Sanitary Precautions in Filter Plant Design.—No cross-connection or interconnection should be permitted to exist in a filtration plant between any conduit carrying filtered or postchlorinated water and another conduit carrying raw water or water in any prior stage of treatment.

No conduit or basin containing purified water should be permitted to have a common division wall with another conduit or basin containing raw water or water in any prior stage of treatment.

No conduit carrying raw water, water in a prior stage of treatment, or drainage from laboratories, toilets, floors, roofs, etc., shall be located in or pass through any conduit or tank containing finished water.

All filter plant drains should be designed to prevent surcharging by flood waters or by drainage water discharged during emptying of tanks, washing of filters, etc. The main filter wash water drain, the clear well drain, and the ground water drain around or beneath the clear well should each be separate and have a separate outlet which receives special attention with regard to protection from flooding. In no case shall these drains be connected to a public storm or sanitary sewerage system.

Toilet and laboratory wastes originating within the filter plant shall be discharged through a separate sanitary system so located and designed that there is no possibility of leakage or flooding of these wastes into the water under treatment.

Where possible, filter plants shall be located on high ground above and distant from public sewers and shall be surrounded by well parked and policed areas.

Disinfection of Water Supplies.—Water may be disinfected by use of chlorine gas, chlorine compounds, iodine and bromine in various forms, ozone, metallic silver ions, ultraviolet light, heat, etc. Of all the known methods, chlorination is the most satisfactory process for disinfecting large quantities of water. Other methods should not be used, except in emergency, without a careful review of the literature to determine their current state of development. The terms chlorination and disinfection are here used to indicate the same process.

Effect of pH on Disinfection.—The effectiveness of chlorine decreases rapidly with increases in pH of the chlorinated water above a value of 7. Available information indicates that the free chlorine residuals required for cysticidal and bactericidal action vary with pH approximately as shown in the table on page 191.

pH Value of the Chlorinated Water	Free Chlorine Residuals After 20 Minutes for Complete Cysticidal and Bactericidal Action	
	Bactericidal Residual Cl_2 ppm	Cysticidal Residual Cl_2 ppm
5	0.2	2.8
6	0.2	2.8
7	0.2	2.9
7.5	0.3	4.3
8	0.5	7.6
8.5	1.3	18.0
9	3.6	50.0
9.5	11.0	154.0
10	34.2	480.0

When alkaline waters are encountered or when hypochlorite is used for superchlorination, the pH of the chlorinated water should be checked and the chlorine residuals adjusted in accordance with the above table. Since hypochlorites may have a marked effect on the pH of some types of water it may at times be better to lower the pH with an acid than to add more hypochlorite.

Chlorination Equipment.—Chlorination equipment should be selected, installed and operated so that continuous and effective disinfection is obtained at all times and so that the hazard of using chlorine gas is minimized. The following requirements should be met:

1. Chlorination equipment should have a maximum capacity at least 50 per cent greater than the highest expected rate of feed.

2. Automatic proportioning of rate of chlorine feed to rate of water treated should be provided at all plants where the flow varies more than 50 per cent from the average. Manual control should be permissible only where the rate of flow is relatively constant and an attendant is always at hand to effect promptly any necessary adjustments in dosage.

3. All chlorination equipment should be installed in duplicate to insure uninterrupted operation. Duplicate units should be operated frequently to assure workability. A complete stock of spare parts and tools should be maintained for emergency replacements and repairs.

4. Chlorination equipment should be capable of satisfactory operation under every condition at the plant. A supply of water, free of coarse suspended matter, should be available under adequate pressure to insure the continuous operation of solution feed chlorinators. Alternative sources of power for maintaining this pressure should be provided where necessary to insure continuous operation.

5. Scales, preferably of the recording type, should be provided for weighing cylinders of chlorine in order to obtain loss-of-weight figures for checking the rate of feed setting on the chlorinators.

6. A sufficient number of cylinders of chlorine should be connected to chlorinators in use to assure adequate operating pressures at all times.

7. A sufficient stock of chlorine gas or chlorine compounds should be on hand to preclude any danger of exhausting the supply of chlorine.

8. Hypochlorite solutions should be prepared in a separate mixing tank, then diluted and allowed to settle so that only clear liquid is withdrawn to the solution storage tank which supplies the chlorinator.

9. The strength of hypochlorite solutions should be checked frequently and should be renewed as frequently as necessary to maintain them at satisfactory strength for accurate control of chlorination.

10. Chlorinators for feeding gas, and cylinders of chlorine should be housed above ground in special rooms provided with exhaust fans that can be set in operation from outside the room, and provided heating, and if necessary cooling facilities to maintain temperature above 60° F. but below maximum outside summer temperatures. Heat shall never be applied directly to chlorine cylinders.

11. Suitable gas masks and a bottle of ammonia for testing for leaks should be kept immediately outside of rooms in which chlorine gas is stored or used.

Chlorination.—Chlorine should be applied continuously at a point where thorough and rapid mixing with the treated water will be effected. Free chlorine should be in contact with all the treated water in a concentration of at least 0.2 ppm for not less than 20 minutes, or chloramine in concentrations of at least 0.4 ppm for not less than 2 hours before the treated water reaches the first consumer.

Where bacteriological and other tests indicate that the above minimum requirements are inadequate a residual of free chlorine of at least 0.10 ppm may be maintained throughout the distribution system, in which case the chlorination at the plant is regulated to provide the desired residual at distant points in the distribution system. At times of threatened or prevalent outbreaks of waterborne disease or of any lapse in water sanitation the residual chlorine should be increased preferably to a minimum of 0.2 or 0.3 ppm in all parts of the distribution system. Chloramine residuals should be at least double the specified free chlorine residuals. Perfectly satisfactory water can be, and in most cases is delivered without any need for carrying residuals throughout the distribution system. The needs for residuals arise through faulty sanitation, for example, failure to properly flush and sterilize new mains or those that have been dewatered, the use of poorly protected open surface reservoirs for storage of purified water, etc. In no case should the maintenance of residuals in the distribution system be looked upon as a satisfactory substitute for proper sanitary protection of the water during distribution.

Operation and Laboratory Control.—Every water purification and disinfection plant should be under the charge of a technically trained supervisor. Plants treating variable or highly polluted raw waters should have continuous and full time trained supervision. Under some conditions small plants may be left in the hands of attendants or operators who lack scientific training but who have been instructed in the mechanical operation of equipment. In such plants the supervisor should be in constant touch with plant attendants. He should be on call in any emergency and should visit the plant as often as is necessary to assure the safety of the water.

For the ordinary filter plant the minimum schedule of laboratory tests should include determinations of turbidity, color, alkalinity, pH, hardness, bacterial counts, coliform bacterial numbers, residual chlorine and, where coagulation is used, jar tests to control the dosage of coagulants. The frequency of tests required for proper operation control of a filter plant depends on the character of the water treated and on its variability. Bacterial counts and coliform tests on the raw and finished water should be made daily. Turbidity and chlorine residuals in the finished water should be determined hourly.

Judging the Efficiency of Operation.—In judging the efficiency of operation of a water plant the following important items should receive consideration:

1. Training and experience of supervisor and operating staff.

2. Adequacy of operation records.

3. Efficiency of laboratory control.

4. Suitability of plant design to the character and pollution of the raw water.

5. Capacity of plant in relation to the average and maximum required output.

6. Freedom of plant from sanitary defects.

WATER PURIFICATION—FIELD AND ADVANCED BASES

Quality of Field Supplies.—The essential qualities to be sought in water supplies for military purposes in the field are: primarily safety for drinking, cooking, and washing; and secondarily palatability. It is imperative that the water be free of pathogenic organisms and toxic chemicals but it is not to be expected that the quality of water furnished in the field shall always be of the high standards demanded by civilian communities as regards appearance and palatability. The military situation, the needs of the moment, the difficulties of transportation, and the sources available determine the type of treatment procedures that must be used.

The selection of sources has been discussed previously in this chapter. The quality of rainwater sources must be protected by preventing contamination of the catchment surfaces and by properly storing the collected water. Wells should be up the slope and as distant as reasonably possible from latrines, soakage pits and other waste disposal facilities. Wells are most frequently contaminated by surface water which flows down the well itself. Therefore, wells must be wired off, good surface drainage provided, the casing or cribbing sealed into the hole with clay or cement, and the cover and upper end of the drop pipe or casing made water tight. Water should be withdrawn from surface streams above or as distant as possible

from camps and villages in the area. In bivouac along a stream or at a watering point the water should be taken or used for various purposes in the following order: (a) drinking and cooking, (b) watering animals, (c) bathing, (d) washing clothes, and (e) washing vehicles. Flags and signs should indicate the zones of use. Sea water should be drawn from beach wells or off shore from the beach at points distant from busy harbors, and from places where wastes are disposed of.

Care must be taken that water rendered safe for use is not recontaminated after purification. Dangerous contamination can be introduced by careless handling or by dipping water from cans with unclean receptacles. When free chlorine has disappeared from a disinfected water, contamination introduced thereafter will not be destroyed. Consequently, in judging the safety of water it is necessary to investigate the quality of the water (a) at the source, (b) after treatment, and (c) at the point of use.

In the field special attention should be given to the following precautions:

1. Regard all water as contaminated unless proved otherwise.

2. Do not permit the use of any unauthorized source.

3. Indoctrinate all hands in the importance of protecting the quality of drinking water.

4. Place guards at points where carelessness might result in serious water contamination.

Canteen Treatment.—This treatment is used by individuals on detached or isolated missions. The use of Chlor-Dechlor vials is at present standard Navy practice. Disinfection of water in canteens may also be accomplished by use of tincture of iodine, Halazone tablets, iodine tablets, sodium hypochlorite and by boiling.

Chlor-Dechlor vials contain sufficient halazone powder to dose a canteen full of water with 15 ppm of chlorine. The vial also contains a coated sodium sulphite tablet which will reduce this amount of chlorine. The coating is designed to prevent the dissolving of the sodium sulphite until sufficient time has elapsed for the chlorine to disinfect the water. To use Chlor-Dechlor add the contents of one vial to a canteen full of water, screw the cap on loosely, shake for 30 seconds to dissolve the halazone, WAIT TWENTY MINUTES for disinfection, then shake again to dissolve the Dechlor tablet which removes the residual chlorine. Agitation of the canteen during the 20 minute wait, as by carrying on the belt when walking, will tend to remove the coating of the sodium sulphite tablet and to dissolve it, thus neutralizing the chlorine before sterilization is complete. If the water does not have a strong chlorine odor before the final shaking, a very high chlorine demand may be indicated. In this case the canteen should be emptied and the procedure repeated using two Chlor-Dechlor units. Adding a second unit to the original canteen of water would be useless. The excess sodium sulphite from the first unit would immediately neutralize the chlorine from the second vial. One of the disadvantages of Chlor-Dechlor is that all of the residual chlorine is removed leaving no protection in case of recontamination.

To use tincture of iodine add two or three drops of a 7 per cent iodine solution to a canteen full of water. Wait 30 minutes.

Two Halazone tablets, 4 milligram (1/16 grain) are required to sterilize one canteen of clear, clean water. If a high organic matter content is indicated by turbidity or color (brown water) four tablets should be used. In either case wait 30 minutes before drinking.

The 0.5 gram Lyster bag tube of Grade A hypochlorite may be used to disinfect water in canteens. Add contents of one tube to a full canteen of water and mix well. Add one canteen cap (6 ml) of this solution to each canteen of water. Wait 30 minutes.

When disinfecting chemicals are not available the water should be sterilized by boiling for at least three minutes. It is often difficult for the individual to boil water, so when boiling must be resorted to the possibility of using large containers and assigning someone to boil water for a group of men should be considered. Tea leaves or ground coffee may be provided to improve the palatability of boiled water and to encourage the boiling operation.

Lyster Bag Treatment.—Companies or smaller units sterilize water in Lyster bags (See Fig. 50) when in bivouac and not supplied with purified water. In view of the difficulty in preventing recon-

tamination of purified water during handling and transportation in the field it is a good idea to sterilize all water in the containers from which it is dispensed for drinking, regardless of whether it has or has not been previously purified. The technic for sterilizing water is as follows:

1. Empty the contents of four glass tubes of Grade A hypochlorite (0.5 grams each) into a canteen cup half full of water and stir to dissolve. Pour this solution into a Lyster bag full (36 gallons) of water. Stir the water with a clean stick or paddle to insure distribution of chlorine throughout. Draw one-half canteen cup of water from each faucet and pour it back into the water bag. This disinfects the faucets.

2. Allow a twenty-minute contact period and then test for 3 ppm residual chlorine as directed on the orthotolidine test kit. The test is made by filling the vial up to the color band, then adding an orthotolidine tablet and shaking to dissolve. After a few minutes the color of the sample is compared with that of the colored band. An orange or yellow color darker than the yellow band indicates more than 3 ppm residual chlorine. The orthotolidine color develops slowly in cold water. Warming the vial in the hand hastens the reaction.

3. If the solution is a lighter yellow than the color band, there is less than 3 ppm residual chlorine. In this case dissolve one more tube of hypochlorite in a little water and add to the Lyster bag. After 20 minutes, test again for 3 ppm residual.

4. When the water in the Lyster bag has shown a residual chlorine of 3 ppm or more after 20 minutes contact, add the dechlorination solution made by dissolving 4 sodium sulphite tablets in a canteen cup half full of water drawn from the Lyster bag. After agitation the water will be dechlorinated and ready for drinking. Since the water does not contain residual chlorine it must be carefully protected from recontamination.

Water may be sterilized in Lyster bags by using two canteen caps full of tincture of iodine (7 per cent) to one Lyster bag full (36 gallons) of water. Water may be boiled in GI cans and, after cooling, poured into Lyster bags for dispensing. The palatability of boiled water is improved if after cooling it is aerated by stirring or by pouring from one container to another.

Disinfection of water in other containers such as water cans, drums, water carts or various types of storage tanks, may be accomplished by the application of a proportional amount of Grade A hypochlorite. For containers of moderate size, i.e., not more than 100 gallons capacity, the Lyster bag method of superchlorination-dechlorination may be used. For larger containers bulk Grade A hypochlorite would normally be used to obtain chlorine residuals after 20 minutes of around 1 ppm and dechlorination would not be attempted.

Water Supply Equipment.—Water purification equipment is supplied to the field for carrying out any combination of the following processes: hypochlorination, chemical coagulation, settling, filtration, and distillation. Equipment for developing a water system includes well drilling rigs, well pumps, centrifugal pumps, pipe, valves, fittings and steel and canvas storage tanks. Detailed instruc-

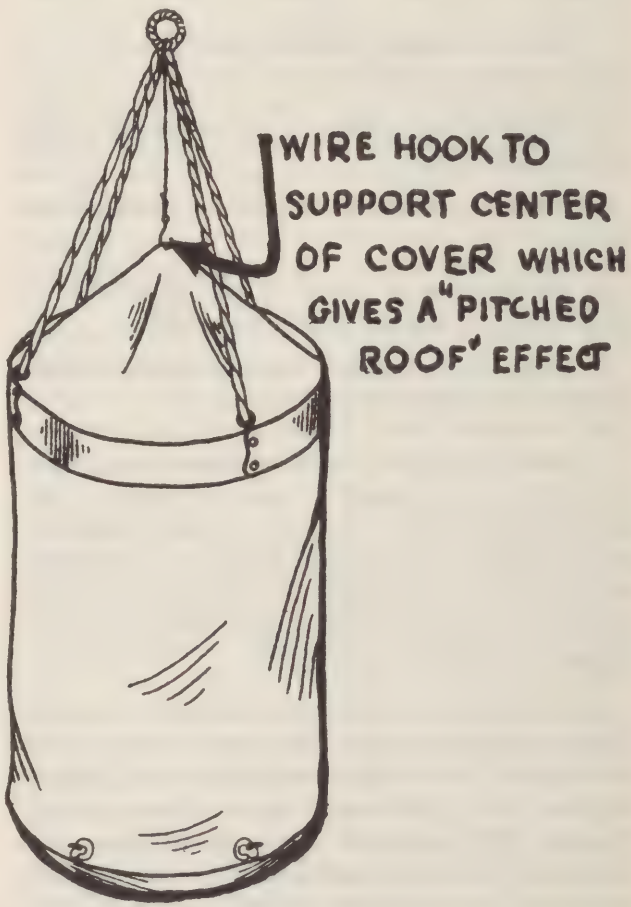


Figure 50.—Lyster bag.

tions for erection, operation and maintenance are furnished with each piece of equipment.

Hypochlorination.—The portable automatic hypochlorination unit is designed to continuously treat flows of 2 to 100 gallons per minute (gpm) of water with a solution of Grade A hypochlorite. By a simple change in the mechanism it can treat up to 400 gpm. Since dechlorination of large volumes of water is not practical in the field, these units are ordinarily set to produce a 1 ppm residual chlorine after 20 or 30 minutes. Simple chlorination to obtain residuals of about 1 ppm will produce safe drinking water from raw water that is clear and free of amoebic cysts. Water that is liable to be contaminated with amoebic cysts must be treated by either filtration or superchlorination. In areas where amoebic dysentery is endemic simple chlorination may be used to treat wash, bath and laundry water supplies while the drinking and cooking water alone is filtered. The chlorination unit is also used to disinfect water produced by distillation units. The portable unit consists of a hydraulically operated hypochlorinator, water meter, pressure regulating valve and a range adjusting valve. The rate of chlorination can be manually or automatically controlled.

Where the hypochlorination unit is not available, chlorination can be carried out by the batch method in storage tanks or other containers. The chlorine solution should be put in the tank or container early in the filling operation in order to obtain adequate mixing.

It is very important that chlorine residuals be checked frequently in the field, at least hourly during the operation of hypochlorinators.

Coagulation, Sedimentation and Filtration.—Coagulation and sedimentation should always precede filtration of water through field type filters. In the past field filters have been issued for use without sedimentation. These units were not highly efficient in removal of bacteria and amoebic cysts and were subject to rapid clogging and attendant operating difficulties when filtering turbid waters or those containing algae growths. The early field type portable filter plant consisted of a chemical and treatment unit and a filter unit. Two 3000 gallon canvas tanks are now furnished to be used with this equipment for sedimentation by the "fill and draw" or "batch" method.

The pump and treatment unit was designed for use when pumping chemically treated water directly to the filter. Since sedimentation tanks are now provided this combined pumping and chemical dosing unit may be economically replaced by a simple pumping unit, in which case chemicals are added directly to the sedimentation tank. Chemicals may be added by use of the treatment unit if it is available or in its absence by either of two methods, (a) making up solutions containing the chemicals required to treat one tank of water and allowing these solutions to trickle into the tank as it fills, or (b) placing the chemicals for one batch in wire baskets which are hung in the tank where the circulating water will completely dissolve the chemicals during the filling operation.

The layout of a portable water purification plant is shown in figure 51. Assuming the treatment unit is used as shown in this figure, the coagulation, settling and filter operating procedure should be about as follows:

1. The pump suction is rigged in the source in such manner that mud will not be sucked up and trash will not clog the strainer. The pump discharge hose is placed on the bottom of one of the treatment tanks, directed so the water will swirl in the tank as it fills. The exact amounts of chemicals needed to treat one tank (2500 to 3000 gallons) of water (see paragraph 5) are placed in the feed pots and the chemical feed valves are set so that the entire contents of the pots are dissolved during the period required to fill the one tank. The hypochlorite tank is filled and the hypochlorinator set to maintain one part per million chlorine residual in the water after it has been filtered (see paragraph 5). Raw water is then pumped at a rate of around 50 gallons per minute into the tank. The filling will require about one hour.

2. When the tank is filled, the pump is shut off, and the floc and clarity of the water is observed. If coagulation is good the water near the surface should be almost crystal clear after a short settling period. If coagulation is poor check the pH and if below 6.0 add soda ash, and in any case add more alum directly to the tank contents and stir the chemicals in thoroughly with a paddle.

3. While the first tank settles, the second tank is filled and settlement started. The chemical doses are adjusted as need therefore is indicated. The proper amount of chemical is placed in the feed pots each

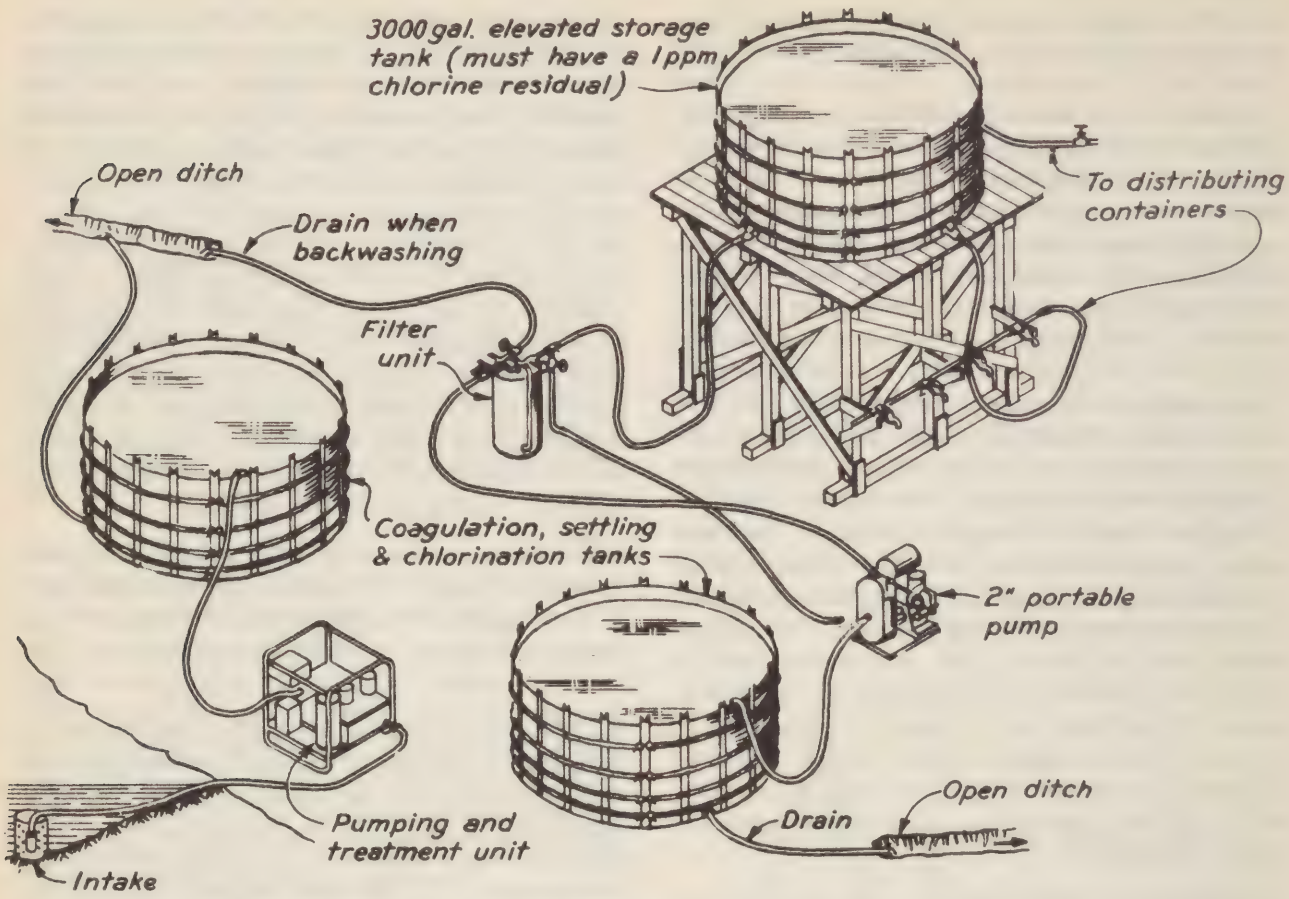


Figure 51.—Layout of portable field water purification unit.

time and alternate batch treatment is continued. The first batch need only be settled for an hour or two. Subsequent batches will have about four hours to settle while the alternate tank is being emptied.

4. Water which has been treated and settled is pumped through the filter unit into the storage tank at a rate of not more than 10 gallons per minute. For the 18 inch diameter filter this amounts to a filtering rate of about 6 gallons per square foot per minute or about double the maximum rate used in municipal plants.

5. Water may be drawn from the settling tank in either of two ways. By the first method the suction hose of the filter pump is carried over the side of the tank and the inlet is suspended just below the water surface. The inlet must be lowered from time to time to follow the receding water level and the pump stopped shortly before sediment on the bottom of the tank would begin to be sucked up. The second method is to attach the pump suction to the tank drain line and pump from near the bottom of the tank wall. This method is successful because the swirling of the tank contents during filling piles the settled suspended matter in a cone at the center of the settling tank where it remains undisturbed when water is drawn at the tank wall. If the filtering rate is properly regulated it should require 5 to 6 hours to draw the clarified water from one tank.

6. The sludge or floc may be flushed from the tank after settling each batch or may be allowed to accumulate for a day or two between flushings. Coagulation is often improved and the amount of chemical needed is reduced by allowing some accumulation of sludge. This sludge will be stirred up during each filling of the tank but will produce very rapid settling.

7. The filter should be backwashed with purified water after each 24 hours of operation or more frequently if necessary to maintain the filter rate. Care

must be taken to avoid washing sand out of the filters. To this end the dirty wash water should be sampled and observed for the presence of sand. Regular washing at the specified intervals will reduce the tendency to loose sand. Filter tanks must be initially filled by admitting water slowly to the bottom of the tank until all air is displaced from the sand and tank. If this is not done the filter will not work properly and sand will be blown from the tank during the first attempt to backwash. Periodical inspections should be made to see that the filter tank actually contains sand.

Either of two types of alum are supplied for coagulation of water in the field: (a) filter alum ($Al_2(SO_4)_3.18H_2O$) which is the type used in municipal filter plants and (b) ammonium alum or war alum ($Al_2(SO_4)_3.(NH_4)_2SO_4.24H_2O$) which is used for pot feeders when the sedimentation process is omitted. Ammonium alum was used only because of its slow solubility rate when pot feeding chemicals directly to the filter. This chemical is much more expensive than filter alum, and twice the weight is required to satisfactorily coagulate water. The slow solubility rate of ammonium alum is actually a disadvantage when coagulation and sedimentation is used as described in paragraph 3. Therefore, although ammonium alum can be used, filter alum is on all counts the chemical of choice. The discussions of chemical dosages in the following paragraph refer to filter alum. If ammonium alum is used, double the stated quantities or weights must be used to obtain equivalent coagulating effect.

Quantities of chemical needed will vary with the water encountered. A 3,000 gallon tank will normally require about three-quarters of a pound of filter alum but requirements may vary from one-half up to twice this amount. One feed pot on the portable treatment unit holds about one and one-half pounds when loosely filled to near the top. Soda ash ($Na_2\ CO_3$) to react with the alum is usually not required in waters that have appreciable natural alkalinity. When waters of low alkalinity are encountered, soda ash may be needed in amounts equal to one-quarter to one-half the amount of filter alum used. If all the alum placed in the feed pot or pots does not go into solution during the filling of one tank, break or crush the lumps to less than one-quarter inch in size. When starting up the treatment plant, the hypochlorinator should be set to give a three part per million chlorine residual in the settling tank during filling. After the filter is started, the residual in the filtered water should be checked and the chlorination of subsequent batches adjusted to provide a residual of one part per million in the filtered water storage tank.

Since the quantity of coagulant and of chlorine is different for different waters and since the required dosages may vary widely with a single source as the raw water quality changes during and after heavy rainfalls, it is desirable to conduct periodically, "jar" or "bottle" tests to determine the proper amounts of chemicals to be used. Several samples of the raw water are treated with various amounts of the chemicals made up in solutions of known strength in order to determine the smallest dose that will produce good clarification or give the desired chlorine residual as the case may be. Stirring should simulate that in the plant. Chemicals are conserved and operations improved by using this procedure.

The above discussion has been confined to operation of the 18-inch sand filter with preliminary coagulation and "batch" sedimentation. Other field units of various sizes should be operated in a similar manner. The important principles to be followed may be summarized as follows:

1. Coagulate and settle the suspended matter before passing the water through the filter.

2. Do not operate sand filters at rates in excess of 6 gallons per square foot per minute.

3. Wash the filter after every 24 hours of operation or more frequently as necessary.

4. Use care to avoid washing sand from the filter and check the filter tank occasionally to see that it contains sand.

5. Maintain a chlorine residual of one part per million in the filtered water.

6. Where possible control operations by treating raw water samples by trial dosages of the various chemicals.

Diatomite Filtration.—Diatomite filters may be substituted for sand filters. The diatomite filter tank houses vertically mounted porous cylinders on which is deposited the diatomaceous earth filter bed. The initial layer of diatomite, the precoat, is

applied by recirculating a suspension of diatomaceous earth. Filtration is then started and a small amount of diatomite, the body-feed, is added continuously to maintain the permeability of the filter bed. When the filter becomes clogged after a few hours the diatomaceous earth cake is backwashed off the cylinders and the operation repeated using fresh material. If the raw water is turbid filtration should be preceded by coagulation and sedimentation. Diatomite filters are smaller and lighter than sand filters of the same capacity but this advantage is offset by the need for supplying the filter aid. When carefully operated these filters produce a high quality water. A failure in the supply of diatomite would render the filter useless.

Distillation.—Distillation units are provided for use where fresh water sources are not available. Single and double effect units were first supplied to the field in 2000 gallons per day and 5000 gallons per day sizes. These units have a distillate-fuel ratio of about 20 to 1. The new vapor compression distillation units now provided have a distillate-fuel ratio of over 100 to 1. These have capacities of around 1700 to 3000 gallons per day and weigh about half as much as the single and double effect distillation outfits per unit of output. The principal disadvantages of distillation are: large fuel consumption, high cost, bulkiness of equipment and the need for highly trained personnel for operation and maintenance.

When distillation is used rigid control of the use of water should be exercised. The allowance of water should not be over 10 gallons per man and preferably not over 5 gallons per man per day. Development of rainfall as a source of water should supplement a distilled water supply and brackish well water should be used for laundry and bathing. It is recommended that well points be used to draw the least brackish water available for distillation and that the equipment be protected from sediment and sand by use of plain settling.

When operating perfectly the distillation process should destroy or remove all organisms. However, experience has shown that perfect operation seldom occurs, so it is necessary to disinfect the distilled water whenever the source of supply is contaminated.

Taste and Odor Removal.—Taste and odors in water are ordinarily caused by high organic content or by contamination of the water with oil or other waste products. Odors which are faint or unobjectionable in the raw water may be greatly accentuated by chlorination. In fact many of the odors which cause complaint against too much chlorine are in fact due to reaction products of chlorine and other substances in the water. Free chlorine itself does, however, impart an objectionable taste and odor when present in amounts exceeding a few tenths of a part per million.

The best solution of a taste and odor problem is to seek a source which is free of organic matter or other troublesome substances. If this cannot be done there are two types of treatment that may be practical for field use: aeration, and treatment with activated carbon.

Aeration can be accomplished most easily by spraying the water into the air above the pure water storage tank. Carbon dioxide, hydrogen sulphide if present, and the volatible odorous compounds will escape to the atmosphere. Aeration not only reduces odors but improves the palatability, especially of distilled water, by adding oxygen. The effectiveness of the process depends on the fineness of the spray and its time of contact with the atmosphere. Aeration seldom removes all taste and odor and in many instances may be altogether ineffective.

Activated carbon is simple to use and is highly effective in removing tastes and odors. Since it is a strong dechlorinating agent it must be applied at a place where disinfection will not be interfered with. In field purification plants, activated carbon will have to be added either in the settling tanks or in the pure water storage tank. If added to the sedimentation tank the water must be chlorinated after filtration rather than at the time coagulants are added. On the other hand, when water is chlorinated before sedimentation, the activated carbon must be added to the pure water storage tank, in which case the residual chlorine will be removed as well as tastes and odors. This is all right so long as the water is well protected from recontamination. The use of small amounts of carbon in the purified water will be neither objectionable nor harmful. The amount of powdered activated carbon required to remove all taste and odor from a 3000-gallon tank full of water ranges from about one-quarter pound up to two pounds. One-half pound to the tank should normally be

sufficient. The powder should be wetted and thoroughly mixed with a small amount of water, then added when the tank is one-half to two-thirds filled in order to obtain adequate mixing.

Sanitation of Water Containers.—All drinking water containers and equipment must be kept scrupulously clean and should be periodically sterilized with boiling water or with a strong chlorine solution (100 to 200 ppm). Canteens, cans, carts, barrels, barges and all hoses and fittings used for handling drinking water must be kept free of the dirt and filth and sterilized as necessary by allowing them to stand full of a strong chlorine solution for several hours. Do not attempt to clean canteens and the like with sand or pebbles unless facilities are available for immediate and thorough sterilization.

SANITARY DEFECTS IN WATER SYSTEMS

Sanitary Surveys.—Sanitary surveys are detailed investigations to locate actual or potential sanitary defects. They may be in the nature of an examination for diagnosis of an illness or they may serve a purpose similar to that of an annual physical examination. Sanitary surveys include any or all of a wide variety of procedures for obtaining both direct and circumstantial evidence concerning conditions which are or may become dangerous to health. Thus such surveys are more than inspections, they are critical studies of all phases of water procurement, treatment and distribution, and may involve review of the records, special field tests, taking of testimony, all supplemented by epidemiological and laboratory studies to establish the facts.

A *sanitary defect* is any structural condition, whether of location, design or erection or any construction or operation practice which may regularly or occasionally cause the water supply to be contaminated from an extraneous source or fail to be satisfactorily purified. When routine bacteriological tests show organisms of types or in numbers that should not be present, an immediate search for the sanitary defect must be made. A considerable departure from accepted standards may demand adoption of emergency sterilization or discontinuance of use until the failure in sanitation has been discovered and corrected. The discovery of the existence of sanitary defects is the pay-off on all routine water laboratory work.

The common failures or deficiencies in water sanitation on shore stations are listed in the following paragraphs for use in locating defects when making sanitary surveys. The sanitary defects are classed according to place of occurrence as follows: (a) laboratory, (b) wells, (c) pumping stations, (d) filter plants, (e) disinfection process, (f) storage reservoirs, (g) distributions systems and (h) plumbing systems.

When the sanitary defect involves contamination by leakage of polluted surface or shallow ground water into wells, underground pipes, tanks, etc., the "dye" or "salt" method of tracing flow to establish the mode of contamination proves very useful. The dyes fluorescein and eosin are best for the purpose. When dissolved in water fluorescein appears, by reflected light, a brilliant green. It can be detected by the unaided eye in dilutions of one part in 40 million and with the aid of a long glass tube, in dilutions of one in 10 billion. A concentrated solution of the dye is poured in the place from which the flow is to be traced and samples of water at the suspected point of contamination are observed for the appearance of the dye. Strong solutions of common salt may be used in the same way, in which case titrations or conductivity tests for chlorides must be made. The salt method is usually less sensitive than the dye method.

Laboratory Errors.—Sometimes bacterial densities higher than should be expected result from difficulties in the laboratory. Check samples should be run whenever counts are high in order to confirm results as well as to provide evidence which may lead to discovery of the sanitary defect. Vigorous prosecution of a field search for the source of trouble should not be delayed while laboratory results are confirmed unless there is definite evidence that the laboratory is at fault

Difficulties in the laboratory which may result in high bacterial counts are:

1. Failure to collect sample properly.

2. Improper protection of sample during transportation to the laboratory.

3. Failure to analyze the sample within a reasonable time after collection.

4. Improper laboratory technic.

5. Improper sterilization of equipment.

6. Faulty culture media.

Certain of these difficulties produce results which may be either much lower or much higher than the true bacterial densities.

Defects in Wells.—1. Improper sterilization of the well or well equipment either when first installed or following repairs.

2. Presence of caves, crevices, sink holes or abandoned wells or borings open to surface drainage or sewage in the vicinity of the well. Common defect in limestone, coral and volcanic areas.

3. Casing of tubular wells leaky, or not extended above ground or above floor of pump room, or not closed at top, or casing improperly used as suction pipe.

4. The annular space between the casing of tubular well and the wall of the hole not properly sealed to prevent flow of surface water or shallow ground water down outside the casing. A common defect.

5. Collecting well or reservoir, or the pump floor subject to backflow of polluted water or sewage through improper drainage. Never drain parts of a water system into a sewer that may be subject to clogging and flooding.

6. Source of supply or structures subject to flooding during periods of heavy rainfall.

7. Leaks in gravity lines or in suction pipes permitting entrance of polluted shallow ground water.

8. Cross-connection between well equipment and a sewer or secondary water supply.

Pumping Station Defects.—1. Leaky underground suction lines.

2. Suction well or reservoir not protected from subsurface pollution.

3. Suction well, pump floor, etc. subject to pollution by backflow through improper drain.

4. Flooding structures and equipment during high water.

5. Contamination of lines and equipment when dismantled for repair and failure to properly sterilize after reassembly

6. Cross-connections with a sewer or secondary water supply.

7. Unsafe water used for priming pumps.

Filter Plant Defects.—1. Excessive raw water pollution in relation to the extent of treatment provided.

2. Existence of nearby uncontrolled sources of raw water pollution.

3. Deficient output capacity or poorly designed equipment resulting in overloading and improper functioning of treatment plant.

4. Improper separation of conduits or treatment tanks and other devices thus permitting leakage of raw or partially treated water into more highly treated or completely treated water.

5. By-pass connections or cross-connections by which raw or partially treated water may be short circuited through the plant.

6. Lack of competent supervision and operation.

7. Inadequate laboratory control or deficient or inaccurate laboratory records.

8. Cross-connections with sewer or secondary supplies, toilet and laboratory drains passing through or over treatment tanks, improper drainage of tanks or equipment permitting backflow of sewage or polluted water, etc.

Disinfection Process Defects.—1. Capacity of chlorination equipment inadequate to meet emergency needs.

2. Duplicate chlorination equipment not available.

3. Insufficient or improper supervision and control of chlorination.

4. Failure to make frequent checks of chlorine residual resulting in failure to adjust chlorine dosage immediately when the chlorine demand of the water or the rate of flow changes suddenly.

5. Failure to keep an adequate supply of chlorine or chlorine compound on hand at all times.

6. Failure to make up fresh chlorine solution as frequently as necessary, when hypochlorination is used.

7. Inadequate mixing and contact of water and

chlorine especially where waters from several sources, some chlorinated and some not, are discharged into a single reservoir.

8. Inadequate contact period and inadequate residual when chlorine treatment is used.

9. Any interruption, from whatever cause, in the maintenance of a uniform and continuously adequate chlorine residual in the treated water.

Storage Reservoir Defects.—1. Inadequate protection of surface reservoirs from inflow of shallow ground water or surface drainage.

2. Inadequate protection of open filtered water reservoirs, from pollution by individuals, e.g. illicit night bathing in reservoirs, picnicking or in other ways using reservoir margin as a park, etc.

3. Wilful contamination of water in reservoirs as an act of sabotage.

Distribution System Defects.—1. Existence of fixed cross-connections between the potable supply and secondary supplies of questionable safety at any point in the distribution system.

2. Cross-connections between the fire and flush systems aboard ship and the potable water supply ashore, with the ship then pumping polluted harbor water into the shore distribution system. Many instances of this have occurred.

3. Failure to properly flush and sterilize new water mains or water mains that have been open for repair.

4. Intermittent service or heavy draft causing vacuum in system, in which case leakage is into the distribution system rather than out of it.

5. Connections to sewers and sewer flushing chambers either for flushing the sewer or for emptying or flushing the water mains.

Plumbing System Defects.—1. Flushometer toilets without vacuum breakers.

2. Water connections to galley and scullery equipment, laboratory and hospital equipment, etc. in which an adequate air gap has not been installed.

3. Cross-connections with unsafe auxiliary supplies on the premises of the consumer.

CHAPTER 8

MEDICAL MATÉRIEL LOGISTICS IN THE FIELD

Standard dictionaries define logistics as the branch of military science that embraces the details of moving or supplying armies and the general conduct of a campaign. A more specific definition for this discussion provides for the delivery of the correct quantity and quality of matérial to the place where needed at the time required. The constantly changing concept of total and global warfare has tremendously increased the problems and difficulties to be met in the practice of matériel logistics. The increased tempo of events to be anticipated from the addition of jet propulsion, guided missiles, and atomic energy to the developments of World War II enlarges the problems and responsibilities of matériel logistic planning. On two occasions seekers for world domination have erred in leaving the United States undisturbed to serve as a reservoir of their defeat. It would be an act of total irresponsibility to assume that such an error might be committed a third time.

The standard training program for medical students and naval medical officers leaves little time for consideration of the problems of supply sources and methods. The ward medical officer prescribes treatment for his patients. The surgeon determines the type and time of operations to be performed and the types of instruments desired. Provision of supplies and equipment, even the determination of numbers of individual instruments required, is left to others. This lack of understanding, on the part of the medical officer, of the problems he is creating adds enormously to the burdens of supply personnel. Logistics personnel have learned that only through complete understanding of the usages and customs of consumers can efficient performance of the supply function be maintained. They cannot afford to adopt the attitude that the consumer either does not know what he wants or needs what he requests. By the same token it is reasonable to expect that requests will be based upon factual knowledge as to what is required, the purpose for which it is intended and the quantity actually needed. The rather widespread practices of ordering new items "to see what it is" and of padding quantities requested "so the depot will have something to cut off" indicates serious misunderstanding on the part of personnel of consuming agencies. In the interest of general understanding and cooperation in common problems a discussion of medical matériel logistics is presented.

The over-all logistic problems of the Bureau of Medicine and Surgery are the responsibility of the Assistant Chief of the Bureau for Planning and Logistics. Under his supervision and control are the Planning Division and the Matériel Division. The Planning Division deals with, plans for, and determines the requirement for buildings, grounds, and fixed equipment for Medical Department installations ashore and afloat. The Matériel Division determines the requirement for supplies other than fixed equipment both as to quantity and time of purchase; and directs and supervises the procurement, inspection, storage, and distribution of the same. Purely financial aspects of logistic consideration are the responsibility of the Finance Division with the Chief of the Division being responsible to the Deputy Chief of the Bureau of Medicine and Surgery.

The fundamental structure of matériel logistics may be set forth by providing accurate answers to four basic questions: "What?" "When?" "Where?" "How?" It is well, however, to bear in mind that such simplification is possible only in the presence of complete understanding of the vast significance of each word in these one word questions.

The term "What?" implies the determination with regard to all items available, which individual items shall be supplied and, with regard to individual items, the quantity of each to be supplied. In practice these calculations are separated into the functions of (*a*) development, (*b*) matériel selection, and (*c*) requirements.

MATÉRIEL SELECTION

Matériel development and selection are the responsibility of the Naval Medical Matériel Board. This board is composed of thoroughly experienced Medical, Dental, and Hospital Corps officers and scientists. Here lies the responsibility for modification of the Army-Navy Catalog of Medical Matériel. The board receives applications from commercial producers presenting items for sale to the Navy and recommendations from members of the Medical Department who desire the addition of an article to the medical armamentarium of the Navy. The board is responsible for a continuing review of the catalog to assure that the selection of items offered there coincides with the changing and advancing practice of sound and scientific medical and surgical procedures.

Upon presentation of an item for consideration by Matériel Board a thorough study is made as to its suitability for use under service conditions, whether it is a duplicate or is superior or inferior to an item already supplied, whether it will serve a necessity of the service commensurate with its cost, and whether it has proceeded beyond the stage of the experimental in sound scientific usage. Under the press of a total war economy, it is needful to determine availability of the item or of the raw materials contained therein. It may become necessary to choose between the new item and one already in use, on the basis of insufficient raw material to produce both. Finally, determination as to availability as a competitive item or sufficient justification for purchase under proprietary certification is required.

All the assistance of wide professional and service experience is available to the board in making determinations. Complete scientific laboratory investigation may be had. The services of the Research Division are available. Specific problems relating to reports of unsatisfactory material and details of development or improvement of items to meet the specific needs are referred to the Engineering Development Division of the Army-Navy Medical Procurement Office for investigation. A service trial and report on the proposed item may be ordered.

In the event that the Medical Matériel Board concludes that an item is worthy of addition to the catalog or should be deleted as no longer required, an appropriate recommendation is submitted to the Chief of the Bureau. In the case of a recommendation to add an item, a statement is included to show the recommended distribution, the quantity of the initial procurement, and the estimated cost. If approved by the Chief of the Bureau, the recommendations of the Board are transmitted to the Matériel Division for appropriate action, including coordination with the Army through the Army-Navy Medical Matériel and Specifications Board.

REQUIREMENTS PLANNING

Sharing the responsibility in the determination as to "What?" and "When?" is the Requirements Branch of the Matériel Division. This branch operates under the supervision of the requirements officer. He is assisted by professional advisers who in turn lend technical and professional advice and guidance to the class or group monitors. To each monitor is assigned a class or group of items listed in the medical catalog. The monitor is responsible for a constant and continuing review of each item under his control. He must be constantly aware of the quantities and location of stocks on hand and on order, rates and types of issues, rates and types of receipts, and rate of deterioration or usage. He must be well informed with respect to plans and programs of the Navy Department, all of which affect the requirement for items under his control. The monitor, with the aid of his professional adviser, must keep abreast of changing uses and customs of professional practice. Failure to do so will certainly lead to distressing shortages or to exasperating excesses.

An illustration of such an incident, which occurred under wartime restriction of information, has to do with penicillin. At a time when production of penicillin was strictly limited by War Production Board order and when issues of the drug had to be limited to cases of infection due to organisms known to be amenable to penicillin therapy, conditions in the field caused the initiation of the practice of prophylactic administration of sizable doses of the drug to recently wounded men. No warning of this practice was sent to supply agencies either before or after its initiation. The first indication of changed methods came only when requisitions began to pour in. The time required to secure new allocations of raw materials from the War Production Board, place contracts, manufacture and test the increased quantities, and distribute the product to a world-wide fighting front led to the development of a most distressing shortage. Fortunately, sufficient matériel was immediately available to meet the crisis at the expense of depleted pipe-line quantities. No personnel suffered for lack of the drug. However, the condition could have been avoided had the requirements officer been advised that prophylactic use of the drug was about to be initiated. No rule or method of mathematics will indicate a requirement for a drug for prophylactic use when orders are to provide only for proved infections from specified organisms. Even in wartime the number of infections can be predicted as can the number of wounds, provided the statistician has accurate information as to the plan of operations. It is not enough for the statistician to secure his basic information from newspaper headlines. But the use of one factor instead of the other is fatally confusing in requirements planning.

The class monitor, under the supervision of the professional adviser, must be constantly aware of the trend of receipts and issues with regard to each item under his control. In the event of a continuing decline in the rate of use for a given item, he is charged with the responsibility for determining the reason for the decline in popularity. Several factors must be considered in such a determination. An advance in medical knowledge may have revealed a better therapeutic agent. Disagreeable or dangerous side reactions may have been traced to the item. The condition for which it is used may have gone into a long period of low incidence. The development of drug-resistant strains of bacteria may have occasioned less satisfactory results from its use. Of further concern in the face of a declining issue rate is the fact that a point may be reached where the quantity required is insufficient to justify stocking the item. It may then be the duty of the monitor to initiate a recommendation to the Medical Matériel Board that the item be deleted from the catalog, provided he becomes convinced that the decline in popularity probably will be permanent.

The frequent changes in practice in the treatments of burns provide an outstanding illustration of the factors just described. Within the experience of persons now in the Medical Supply Service the therapeutics of burns has involved Carron oil, picric acid solution, paraffin spray, tannic acid solution, tannic acid and silver nitrate, tannic acid jelly, medicated petrolatum, and pure petrolatum. One element of this picture presents a real puzzle. Since the advent of the use of tannic acid solution in the therapy of burns the rate of issue of tannic acid powder has remained almost constant. There were minor decreases in rate of issue with the advent of each new therapeutic regimen. That tannic acid powder is not used for burns or for other purposes is indicated by the fact that returned stores of this item from decommissioned activities often closely approximate original issues. The small quantities not returned probably represent the amount used for astringent solutions and ointments. Yet the current rate of issue remains fairly constant.

In addition to maintaining stock levels of all items against changing demands of current operations, the Requirements Branch is accountable for keeping sufficiently informed as to new concepts of warfare, new offensive and defensive weapons and tactics, and new developments in the fields of preventive medicine and in therapeutic medicine to assure that items and quantities available for issue will be those, and only those, items and quantities the future need for which may reasonably be anticipated. It should be emphasized that the full discharge of this responsibility implies a breadth and depth of vision quite beyond the popular conception of the role and capabilities of a requirements planning group. Yet such emphasis points up the importance of the position of correct and realistic requirements planning in the over-all

schedule looking toward the preservation and perpetuation of our country.

Not only is the requirements planning group responsible to provide for the needs of the Navy in peace and in war; all too often there are emergencies involving the civilian economy and health to an extent that surpasses the capacities of civilian agencies. In such situations reserve supplies of the armed forces are required for immediate alleviation of civilian need. Three instances in point have to do with the threat of a smallpox epidemic in the Pacific Northwest in 1946, a similar threat in the New York area in 1947, and the recent cholera epidemic in Egypt. In these instances large quantities of vaccine were obtained from the Naval Medical Supply System.

Thus far the discussion of requirements planning with respect to quantities has been deliberately misleading in that only quantities for use have been indicated. This deception was intended to point up a most confusing and little appreciated element of the logistic problem which has to do with "pipe-line quantities." It may be recalled that at the time the "Big Inch" pipe line was placed in service it required about 3 weeks continuous pumping to fill the pipe line before delivery at destination began. The volume of oil required in the filling process can be obtained by a relatively simple calculation. The determination of pipe-line quantity in medical logistics is a much more complicated problem.

The term "in the pipe line" may be applied to all stores nominally under the control of the medical supply system from the time of receipt from the manufacturer until all consuming activities have a sufficient quantity in their storerooms to provide for day to day requirements. Actual rate of use figures from consuming agencies must form the basis for estimating quantities required. Each consumer should determine his rate of use per month for each item. From that basic figure a determination is made as to the minimum below which stock on hand may not safely go. In the same manner there is established a maximum to which stock should be held in the interest of economy. Minimum and maximum quantities ordinarily are established by Bureau orders. An intermediate level, the order point, is established. This level should be the requirement for the minimum period, increased by the requirement for the average period of time required to receive delivery of material on routine requisition. Where the minimum is established as stock for 6 months, the maximum is stock for 12 months, and the requisition time is 2 months; the order point would be set at 8 months. When the stock on hand is depleted to the order point a supply for 6 months should be requested. Normal delivery 2 months after order would not exceed the maximum stock period.

Because it is not feasible to compile usage rates from every consuming activity, requirements planning personnel assume as such usage rates the rates of issue from medical supply issue points. These rates of issue are carefully compiled on a monthly basis. However, the problem is not quite so simple. Quantities issued on requisitions may be for normal use (recurring issues), or to expand an activity or to augment the working stock (nonrecurring issues). By way of keeping the pipe-line quantity accurate these two types of issues are tabulated separately. Only those quantities classed as recurring issues are considered in the determination of usage rates. Determination of requirements to satisfy nonrecurring issue demands must be made through accurate advance information regarding plans of operation and medical department programs.

In addition to tabulations of issue data it is necessary to consider sources and types of receipts in the establishment of usage rates. For this purpose receipts are classed as receipts from purchase and receipts from returned stores. The latter is subdivided into receipts from decommissioned activities and those reduced in capacity and receipts from activities where excess quantities have been accumulated. Only those receipts from excess quantities affect the usage rate.

Another source of information is developed by a study of property surveys. Quantities, particularly of dated items, appearing on property surveys indicate that more was ordered and received than could be utilized prior to potency expiration. In using information from surveys the monitor must be careful to check procurement and stock status. There are occasions when the exigencies of procurement require that stocks be issued so close to the date of expiration that full utilization of the material cannot be expected. Such a situation has

occurred frequently with respect to x-ray film and certain biologicals. In order to avoid certain loss it is requisite that such items be ordered in quantities sufficient for the requirements for only half the normal potency period.

These components are combined to provide a usage rate which is then adjusted to the established maximum stock period. Thereafter the adjusted usage quantity is combined with planned requirements for nonrecurring issue and pipe-line quantity to provide a maximum stock quantity. Upon this basic calculation there is then established a maximum stock quantity and an order point in the same manner as that described above for the consuming activity.

The final phase of the requirements planning function is the requirements review period. At specified intervals the requirement for each item of medical matériel is reviewed and adjusted as may be indicated by variations that may have occurred in any of the factors noted above as affecting the anticipated need. The frequency of periodic review is determined with respect to each item after consideration of individual characteristics. Of particular importance are durability, volume either as to storage space requirement or as to monetary value, and procurement lead time considered with impact upon industry. The latter term may well be expanded. Procurement lead time refers to that period between preparation of a purchase order and receipt of the product within the Medical Supply System. The impact of government orders upon industry must be carefully gaged if efficiency and economy are to be attained. In the case of some items the volume of required quantities may be so small as to indicate annual purchases. In other instances the volume or the durability may be such as to indicate monthly procurement. With respect to items of seasonal production it may be advantageous to so place contracts as to allow production for the government to coincide with periods of slack production for the civilian economy. With respect to certain items, special tools and production methods are essential. In that event relatively infrequent individual purchases are more economical as well as producing a smaller degree of disruption of industrial productivity.

The next step in the review of requirements is to establish the relationship between the quantity required and the quantity available and thereby to determine the quantity to be purchased. The formula for this determination requires that the total quantity required for the determined review period shall be reduced by the quantity on hand in the Medical Supply System, the quantity on order from contractors, and the quantity that it is estimated will be received as returned stores. The estimation of quantities to be received as returned stores can be made on the basis of past receipts adjusted to allow for known or anticipated decommissionings or reductions of naval activities. The resulting unsatisfied requirement is further adjusted to cover the factors discussed as determinative in the establishment of the frequency of the requirements review period. Finally, the portion of required quantities remaining unsatisfied is adjusted by a factor for contingencies. The contingent factor is the final expression of the judgment and intuition of the requirements planning officer. It may be heresy to admit that intuition has a place in sound planning. Yet the possession of an imaginative understanding of the fundamental principles of logistic planning, intuition, is the crowning glory of the successful requirements planner. In any event the finally adjusted requirement is transmitted as a purchase order to the Army-Navy Medical Procurement Office.

ARMY-NAVY MEDICAL PROCUREMENT OFFICE

The functional organization and accomplishments of the Army-Navy Medical Procurement Agency and of the Army-Navy Medical Procurement Office have been adequately described elsewhere. It is sufficient for the purpose of this discussion to say that ANMPO (Army-Navy Medical Procurement Office) arranges the purchase, inspection, and delivery of material in the quantities, at the times, and to the places within the Medical Supply System designated by the Requirements Branch of the Matériel Division. It is, however, considered to be advisable and conducive to a clear understanding of certain situations that have developed or may be expected to develop, to comment briefly upon those elements which tend to detract from the ideal picture indicated.

It is necessary that the requirements planning group be adequately informed regarding market conditions and industrial potential as affected by

the factors of availability of raw materials, the condition of the labor market, and the demands of the civilian economy, yet it is not reasonable to expect the planning group to maintain as intimate information of these factors as must be demanded of the purchasing group in ANMPO. Occasionally there has been severe criticism of the Medical Supply System because items were in short supply or out of stock because deliveries from contractors had been delayed weeks or months beyond the time specified in the contract. In some cases the delay has been due to incoordination between the planning and procurement functions. In other instances the delay has been due to unusual conditions in industry. The Nation's economy continues in the phase called the "seller's market." That is to say that there is a ready demand for any and all products with little discussion as to price or terms.

For so long a period as the civilian economy can easily absorb the entire volume of industrial production, a federal contracting officer is at a distinct disadvantage. Contractors not only do not seek government contracts but in many instances are actually loath to accept proffered business and often actually refuse to respond to requests for bids. Such a tendency is augmented by the natural inclination of a producer engaged in the competition for civilian markets to be assured that diversion of goods to fill government contracts will not weaken his position in the competitive market in the future when the advantages of the "seller's market" have disappeared. Here rests the explanation for the fact that individual hospitals frequently are able to buy the small quantities required for local use when the large quantity needed for the entire system cannot be procured.

DISTRIBUTION

The requirements planning and procurement functions of logistics have as their primary purpose the timely delivery of adequate materials to the consuming agencies of the Navy. Satisfactory accomplishment of that purpose requires that centralized procurement be supplemented by a suitable operative organization for distribution. Such an organization must serve to receive and store materials and to distribute individual items to supply the needs of consumers. Because the primary function of distribution is to supply the needs of the individual consumer, it follows that distributing points must be established at such locations as will provide to each consumer the best service it is possible to attain. A secondary purpose, and one that becomes increasingly important, is such dispersion of stored material that loss or destruction of one or more storage areas will produce the smallest possible disruption of service.

MEDICAL SUPPLY DEPOTS

In the Naval Medical Supply System the operative functions of distribution are delegated to the medical supply depots. At the high point of World War II the Medical Supply System comprised 5 medical supply depots, 10 named medical supply storehouses, 14 numbered supply storehouses, and, for mobile supply of the fleet and Advance Bases, 8 medical supply barges and medical sections in 27 general stores issue ships (AK's and AKS's), and several medical supply facilities which were subsidiary to various ones of the numbered storehouses. With the termination of hostilities, the general reduction in force was applied to the Medical Supply System. At the close of fiscal year 1947 there remained 4 medical supply depots, 1 named storehouse, since disestablished, and 3 medical stores sections of naval supply depots. For purposes of stock control and accounting, these activities were organized into 4 control points. The Naval Medical Supply Depot, Brooklyn, N. Y., is the control point for East Coast activities, including the Medical Stores Section, Naval Supply Depot, Mechanicsburg, Pa. The Naval Medical Supply Depot, Oakland, Calif., is the control point for West Coast activities, including the Medical Stores Section, Naval Supply Depots, Clearfield and Spokane. The Naval Medical Supply Depots, Pearl Harbor and Guam, serve respectively as control points for the Hawaiian and Marianas areas.

STOCK CONTROL AND WAREHOUSING

These closely associated phases of operational logistic practice provide concrete answers to the last two basic questions of sound matériel logistics. The stock control function envisages the maintenance of records as to what is received, when it is received, where, and from what source; as well as recording what is issued, when, and to what activity. Warehousing duties include the physical receipt, handling, storage, issue and shipment of materials when and as directed by stock control.

It is essential that there be very close coordination between the stock control and warehousing functions in the determination as to where material is to be received into the Medical Supply System and the storage point or points from which issues are to be made to satisfy the requests of consuming agencies. The controlling factors in these determinations have to do with the availability of storage space suitable for each type of material, packing and handling capacity, and accessibility to transportation both into and out of storage.

The stock control function of the Medical Supply System is centered in the Inventory Control and Requirements Review Sections of the Requirements Branch and the Accounting Branch of the Matériel Division. The Accounting Branch concerns itself only with procedures of fiscal accounting for materials for which the Matériel Division is responsible. The Inventory Control Section is responsible for an equitable distribution of stocks of medical stores between the several major distribution points of the system. In addition, there is the responsibility for supplying to the requirements officer information regarding stock received, issued, and remaining on hand, so tabulated as to provide the type of information required in the process of requirements review.

The actual performance of the stock-control function is accomplished at the point of ultimate issue from the Medical Supply System to the using agency. At a specified time each month a Stock Status Report is prepared at each control point and forwarded to the Requirements Review Section of the Matériel Division where the four basic reports are consolidated into a single report from which information as to Navy-wide receipts, issues, and stock on hand is provided. Two other reports should be mentioned here in the interest of a clearer understanding of the discussion to follow. The first of these is a monthly report covering all items bearing a date of expiration of potency and giving for each item the date of expiration and quantity of each manufacturer's lot number. The second is a monthly report of storage space occupied, obligated, and available, and the weight of stores received and shipped during the month.

In the determination of the "Where?" of medical logistics, the Inventory Control Section of the Matériel Division consults the individual reports just outlined to determine the relative position of the several control points both as to stock on hand and storage space available. Under ideal conditions it would be possible to redistribute stock between control points as might be required. Actually as funds available for "Transportation of Things, Navy" have been reduced, the ideal solution is no longer possible. Under present conditions the only redistribution that is possible is that which may be accomplished by careful allocation of contract deliveries from new purchases. Strictly speaking, such a limitation has a salutary effect for the reason that it commands a more careful allocation of stores in the first instance because there can be no correction of errors by reshipment of stores.

The mechanics of stores allocation finds a basis in the concept of areawise distribution. Essentially the Brooklyn Depot, with bulk storage at Mechanicsburg, Pa., serves the area eastward from the Continental Divide, including Atlantic and Caribbean areas. In like manner the Oakland Depot, with bulk storage at Clearfield and Spokane, serves the area westward from the Continental Divide, including Pacific and Alaskan areas. Contract deliveries are scheduled to control points at Brooklyn and Oakland. Pearl Harbor and Guam secure replenishment by transfer from Oakland. Primarily the Matériel Projects Section establishes a tabulation by areas of numbers and types of personnel, hospital patients, and activities. From that tabulation, new procurements of medical stores are allocated percentagewise to the two major areas. The basic allocation is adjusted to equalize existing stocks and to provide for anticipated demands on the basis of usage rates established through data supplied on Monthly Stock Status Reports and further modified in line with known or anticipated changes in personnel numbers as well as types and sizes of activities. The adjusted basic allocation is further reviewed by items for such modifications as may be indicated by the use for which individual items are intended. For example, components of field outfits are distributed in accordance with the basic demand for such items and modified as the operating plan anticipates variation in the area assignment of Advance Base and Field Forces.

Preparation for the receipt within the Medical Supply System of medical stores begins with the Requirements Review Section of the Matériel Division. Each stock-control point is informed as to quantities of individual items proposed to be stocked in spaces under that supervision. The quan-

tities thus established are based upon the basic stock allocation desired, unless further modification is required by limitation of storage space under the supervision of the individual control point. The final quantity is transmitted to the designated control point.

Upon receipt of basic stock-allocation estimates the Stock Control Branch of the Medical Supply Depot supplies information as to the anticipated rate of issue as well as the estimated average quantity, and the range of quantity for individual issues, for each item. In the case of Oakland, the quantities to be transshipped to Pearl Harbor and Guam are added. Estimates are then passed to Warehousing Branch personnel for establishment of definitive delivery points and final preparations for physical receipt of material.

Determinations of warehousing personnel are based upon the consideration of space availability, storage characteristics of spaces available, transportation and packing facilities; and, with regard to individual items, type of storage required, degree of security required, probable ultimate destination, amount of space required, probable rate of issue, and the probable number of issue units required by the average requisition. An additional and increasingly important consideration is the need for strategic dispersal of supplies and equipment to provide a reserve against total loss of an item through a single incident. To illustrate the problems involved in the preparation of a warehousing plan, a few instances are cited. Where the maximum stock quantity of one item may occupy one or two cases and require less than the 9 square feet of one pallet space, another item will fill several thousand cases and require many hundreds of square feet for storage space. One item may require one or several cases for a single unit of issue while another item may be so packaged that a single case contains several hundred issue units. Varying degrees of security may be required and for varying reasons. For example, stop watches require security to avoid simple pilferage while narcotics for obvious reasons require maximum security. Certain vaccines require storage at freezing temperatures while others require only moderate chill box storage and are damaged by freezing. Some drugs and solutions require heated storage to avoid cold weather loss by freezing. Other items require chill storage to avoid extremes of summer heat. Some items must be stored separately because of the danger of fire. An outstanding example is provided by methyl salicylate and calcium hypochlorite. These compounds, if brought in contact, produce fire with explosive suddenness.

The typical medical supply depot warehousing officer begins with the preparation of a floor plan or diagram of all available storage space. The characteristics of each area are indicated. The most suitable area is set aside for shelf or bin stock. In this area space is provided for each item for which the issue unit is less than the contents of a shipping case. Spaces are arranged and marked in catalog sequence. Space allotted to each item is determined first by the size of a case of the item and secondly by the number of cases normally issued within the time usually required to secure resupply of shelf stock from bulk storage areas.

Adjacent the shelf area, space is set aside for packing where items of shelf stock to fill individual requisitions are packed for shipment. Another space is set aside for assembly of case lot material from bulk storage spaces with repack cases from shelf stock so that all material for a single requisition can be delivered to the shipping space as a unit. Remaining space is established for bulk storage by items in case lots. This space is subdivided as indicated by storage characteristics. Storage bays are established and identified by area and number, fire lanes and stores handling aisles are marked out, and finally the net floor area and floor load limits are computed for each type of storage available. In general, the parent depot provides refrigerated and security storage, and bulk storage to back up shelf items. Medical stores sections of inland depots provide general bulk storage from which large shipments of case lots extracted from requisitions may be taken.

The next step is to establish space and weight requirement for storage of maximum stock quantities as indicated by the stock control branch and to set aside the required space of the correct type of storage for each item to be stored. In the event that space available is less than the space required some adjustment may be made on the basis that some items move too rapidly to permit stock on hand to reach the maximum level as established. In no case is it safe to set up space for less than the minimum established level for a given item. On the other hand a reserve of space must be held

against the possibility that some items may go into long supply for various reasons.

With specific space assignments prepared as described, the warehousing officer prepares shipping instructions in three categories: (1) specific delivery point for all items which must be stored at the parent depot for reasons of security, refrigeration, or small bulk; (2) percentage-wise deliveries for all items for which storage space availability may be calculated far in advance by reason of bulk, dispersion or rate of issue; (3) deferred determination for all items for which delivery point must be established specifically for each order after quantity and delivery date are known. After approval of delivery information by the stock control branch it is returned to the Requirements Review Section of the Matériel Division. Thereafter, as procurement directives are cleared by the Division specific delivery points are indicated for group 1 and 2 items. For group 3 items the depot is notified as to quantities and delivery dates on procurement directives and specific delivery point or points become an addendum to the procurement directive.

INSPECTION

An essential element of procurement for gov ernment agencies is the mechanism by which assurance is had that materials delivered are the same quality and quantity as that for which payment is made. In medical procurement there is the additional responsibility for assurance that materials are safe for use. This responsibility is pointed up by repeated instances during World War II in which large orders of intravenous fluids were found to be grossly contaminated. A very striking example is the instance in which a shipment of tablets purchased as sulfathiazole were found during inspection to be phenobarbital. Drug manufacturers had their problems with inexperienced, careless, incompetent help as did other activities.

Inspection in the Naval Medical Supply System is a divided responsibility. Basic production inspection, contract management and general release procedures are the responsibility of the local office of the Inspector of Naval Matériel under direction and supervision of the Inspection Branch of the Army-Navy Medical Procurement Office. Technical inspection of finished products is the responsibility of the Laboratory Branch of the Army-Navy Medical Procurement Office. Final inspection as to transit damage, verification of marking and packaging, and certification as to quantities received is the responsibility of the receiving and inspection officer in the receiving depot. Reports of all predelivery inspections are delivered to him for final correlation.

RECEIVING

Upon physical receipt of a shipment of material at a medical supply depot, receiving department personnel prepare a standard record of receipt. If all inspection procedures are not found to be in order the material is held in that department until the defect is corrected. Upon satisfactory completion of all inspections the material is accepted and forwarded with necessary documents to warehousing spaces for storage. At the same time receiving documents are sent to the Stock Control Branch where the quantities are added to continuous inventory records and issues to consuming agencies may then be initiated. From the Stock Control Branch of the depot the receiving report is transmitted to the Matériel Division where appropriate entries are made in records maintained by Requirements and Accounting Branches. Originals of receiving documents are forwarded directly to the Fiscal Branch of the Army-Navy Medical Procurement Office and become the final authority for preparation of vouchers upon which the contractor is paid.

REQUISITION PROCESSING

The preparation of requisitions by consuming activities for needed medical supplies and equipment has been adequately explained by Bureau Circular Letters. It is intended as constructive criticism when it is stated that many activities either do not read and understand current circular letters on the subject or consider that it is too much trouble to follow instructions. In any case, the fact is that considerably more than 50 percent of requisitions received are found to be in error in some degree. It has come to be accepted as not unusual to receive frequent requests for changes in requisitions, either as to quantities or as to required delivery date. To facilitate the handling of such requests an elaborate system of requisition control has been found to be essential. Immediately upon receipt of a requisition in the depot, the

number and date of receipt are recorded on the requisition progress control card for the specific activity. The date of completion of each step in processing the requisition is entered on the same card. By this means any requisition can be quickly located at any stage. From the progress control desk the requisition is sent to the short supply control where items requested which are out of stock or in short supply are indicated. Errors in preparation as to expendability or stock number are noted. The next step is action by the requisition review board. This board is made up of medical and dental officers of wide experience who activate the basic policies and specific orders of the Bureau. The requisition is examined for correctness of preparation, a determination is reached that the activity is or is not entitled to the items requested under Bureau orders, and that quantities requested are in line with established allowances. Items out of stock or in short supply are placed on back order or reduced in quantity as appropriate. Every effort is made to serve the minimum needs of all activities so far as limited supplies will permit. The ideal is to have adequate supplies of every item to fill all requests as received. Such a situation will not prevail in the face of a continuation of a seller's market and exorbitant requests. The writer personally investigated a requisition in a case where it developed that the activity had a 4-year supply of the item in question and had requested enough for an additional 3 years. In that case it developed that the request was prepared by a stock clerk and had not been verified by any other person until it reached the depot.

From the review board the requisition is sent to stock control where items suitable for issue from bulk storage locations are indicated. Next, to machine records group, where priced invoices are prepared. Completed invoices are sent to appropriate storage locations where the materials are assembled, packed, marked, and request for bill of lading prepared. The shipment then moves to the shipping section and papers to the transportation officer for preparation of bill of lading and shipment booking. At this point it is well to stress that, in the absence of specific justification, only routine shipment by the most economical carrier is permitted. This limitation is imposed by Departmental authority and arises from limitation of appropriated funds for transportation. It is not enough to write "Emergency" on the requisition or to send a dispatch request for "Air shipment." Nor is simple failure to anticipate requirements sufficient justification for expedited and therefore more expensive shipment. Specific reasons in justification for expedited handling are necessary. Packages up to 4 pounds may be shipped as franked mail. Packages weighing 4 to 70 pounds are forwarded by parcel post at a cost for postage less than the cost for express shipment. With sufficient justification supplied by the requesting agency, 100 pounds for railway express or 10,000 pounds by freight may be shipped without a route order. In the absence of supporting facts to justify more expensive handling, all shipments must await transportation by naval vessels in coastwise transit or consolidated trapcar shipment for railway movement.

INVOICING

Requesting agencies are justifiably anxious to learn the fate of their requisitions. The invoicing procedure is arranged to meet this need. Upon completion of requisition review procedures, the second copy of the requisition showing all alterations, each indicated by a symbol, is mailed to the requesting agency with a form letter explaining the meaning of symbols used. As soon as the priced invoice has been prepared, the original (first) copy is mailed to the requesting agency. Upon receipt of the material this copy is to be receipted and mailed directly to the Matériel Division, Bureau of Medicine and Surgery, 84 Sands Street, Brooklyn, N. Y. At the same time copies two and four are mailed by the depot to the Matériel Division with supporting documents. Copies three, five, and six are sent to the storage section for use in assembling the material. As assembly progresses the case number or numbers for each item are indicated in the right marginal space. These copies with the request for bill of lading are sent to the transportation office. Upon completion of bill of lading the third copy of the invoice and the consignee's copy of the bill of lading are mailed to the requesting agency and should be held as file copies. The fifth copy is sent to the shipping office where it is placed in waterproof covering and securely attached to case number one of the shipment, as the packing copy. The sixth copy complete the files of the issuing depot.

CONCLUSION

In the interest of unification of effort and in the hope of greater understanding and simplification of mutual problems and responsibilities, an expanded outline of the task, the difficulties, and some of the solutions of medical material logistics has been presented. Unfortunately, the subject does not lend itself to humor and space does not permit the use of the multitude of examples from which reader interest might have been drawn. All reference to statistical data, as such, has been deliberately eliminated. The goal of matériel logistics is the delivery of exact quantities of exact items at exact places at exact times. That goal is something for which to strive but probably not to be attained. Logistics personnel hope that, with a great share of help and cooperation from operating forces, they may continue to improve and progress.

THE DISTRIBUTION AND USE OF HUMAN WHOLE BLOOD IN THE PACIFIC WAR

From the destructive processes of war there always seem to emerge some bright and encouraging elements, as if there were somewhere an attempt at counteracting the disasters. The perfected distribution of human whole blood by air, over thousands of miles in the Pacific theater, through hot tropical climates, to the front lines of battle deserves to be included in that list of "bright and encouraging elements."

This complete report, both historical and factual, is being made in some detail, for it is inestimable just how many lives were saved by the ready availability of this human whole blood during the war. From the results and data herein related this report will act as a guide to the many civilian blood banks and whole blood programs which now are being contemplated and started. Also contained is the report on one of the largest groups of data on transfusions and their reactions in the history of blood transfusions.

HISTORY OF THE NEED FOR THE PROJECT

The war clouds gathered in 1939 and 1940 and the medical profession of the combined services along with that of the civilians became greatly concerned over the preparation for war if and when it should come. The usage of plasma had already proved itself a most valuable agent in restoring the circulating blood volume in the shock state (secondary shock resulting from trauma); accordingly, all emphasis was placed on a plasma program sponsored by the American Red Cross and supervised by the Army and Navy Medical Departments, with expert technical advice from members of the National Research Council Subcommittee on Blood and Blood Substitutes, and the National Institute of Health. Thus, in discussion and planning at such meetings as that of the Human Serum Association at Cleveland in June 1941, the problem of drying and storing human plasma was the paramount factor of consideration.

The whole blood requirements at the beginning of the war were to be cared for in the individual hospital, ship, or station where the bleeding of donors was to be done according to demands. This plan seemed at that time to cover all of the necessary exigencies.

The wars began, and with the advent of the Solomon Islands and north African campaigns of August and November 1942 respectively, much was learned as to the additional needs of modern medicine in battle. It was evident from the very first of the conflicts with the enemies in both theaters that whole blood in addition to plasma would be needed in increasing quantities. Considerable assistance was obtained from the British in North Africa who had previous war experiences due to their early entry into the war.

In the Mediterranean Theater, Col. E. P. Churchill, (MC) AUS, set forth appeals for more and more whole blood procurement to meet the needs of battle. The emphasis grew stronger, and through the untiring efforts of Maj. E. Sullivan (MC) AUS, in addition to stimulus resulting from the bitter struggle at Anzio in Italy in January 1944, a blood bank was established on 23 February 1944 in connection with the 15th Medical Laboratory in Italy under the direction of Maj. J. J. McGraw, (MC) AUS, and for the remainder of the war this facility supplied the needs of that theater from their own donors in a most efficient way.

In the early Pacific warfare also, as in the bitter battles of the Solomon Islands, the need for whole blood in large quantities, from sources other than troops and fighting personnel, was demonstrated. For here under the worst tropical conditions, with malaria rampant, it was not possible to procure

adequate donors to meet all demands. Early in the South West Pacific, then, blood was first obtained in part from Australia, later from the medical facilities at Hollandia, and still later from the *LST 464* which acted as a floating blood bank.

With the progress of the European war there were initial plans to be prepared to provide 1 pint of whole blood for every four to five casualties on the Normandy landings, and later this was revised to 1 pint per two casualties. There will be more discussion of this later.

In the main the Pacific warfare differed considerably from the European. In the Pacific conflict, as it reached its height with multiple island invasions, the essential difference was that large scale medical care was much nearer the wounded, in the form of hospital ships, LST's, well-equipped APH's and APA's, landing medical parties, and later the medical shore installations as well as air evacuation planes; whereas, in Europe large land territories had to be covered, and personnel, both troop and medical, was much more spread out. Take for example the campaign of an Army in France as compared with the Invasions of Tarawa or Iwo Jima where the entire plot of land was not more than a few miles long and much less wide, and yet there were really stupendous medical forces backing them up. With the attacks on such heavily fortified areas increasing, coupled with the brilliant use by the Japanese of mortar fire and other weapons, the most terrible type of wound was inflicted, with men being literally blown in two and yet still living. These patients were promptly brought to medical stations in such a state that survival seemed impossible. Accordingly, the average of 1 pint per casualty in the Pacific did not seem so heavy if the above picture is borne in mind.

With such an introduction then the need for whole blood in much larger and readily available amounts was more and more evident. Thus in August 1944 the United States Army started flying human whole blood to the European Theater of Operations, and in November 1944 the Navy began flying it to the Pacific Theater of Operation. Just prior to this, Lt. E. E. Muirhead, (MC) USNR., under the direction of Capt. A. T. Walker, (MC) USN, Fleet Medical Officer to the Seventh Fleet, maintained a remarkable and excellent blood bank service for the South West Pacific areas on the *LST 464*, where donors for this theater were obtained. All of this blood, however, had to come from service personnel. Once the problems of transportation and refrigeration were solved the supply of whole blood from donors in the United States was more than adequate to satisfy all Army, Navy, and Marine needs in all areas, without drawing upon service personnel in the forward areas, an expedient which was necessary to meet demands.

PREPARATION STAGES

Two major topics are considered and their solutions are related, as follows:

(a) *Early Transportation of Whole Blood by the British Army.*—On 12 February 1944 in the Journal of the American Medical Association, Whitby *(1)* described the activities of the British Army Blood Transfusion Services. They had collected and distributed 8,790 pints of whole blood for the British, Norwegian, and French campaigns as well as for home forces and civilian usage. There were even wicker baskets for the containers so that parachute drops were made at Dunkirk. These bloods were all type "O," Kahn negative, and were shipped in insulated boxes with central water ice units. Although their system was basically similar to the eventual Navy system, much more had to be taken into consideration for the Navy's long shipments, under tropical conditions as well as other factors.

(b) *Increasing Demands for Whole Blood in Pacific Theater and Problems Therein Concerned.*—With each ensuing invasion in the Pacific from Tarawa on there were increasing demands for more and more whole blood for the Pacific Ocean areas. In order to meet these demands, and send blood from the United States, the following problems had to be solved, many of which at first seemed almost unsurmountable. They were:

Distances in the Pacific.—A first concern was the extreme distance to be transversed, with many thousands of miles between the Pacific Islands as well as thousands more from the United States.

To illustrate more fully the distances in the Pacific, here are some of the approximate mileages: San Francisco to Honolulu, T. H., 2,087 miles; Honolulu, T. H., to Kwajelein, 2,124 miles; Honolulu to Guam, 3,668 miles; San Francisco to

Guam, 5,755 miles; San Francisco to Philippine Islands, 7,141 miles; and New York to Tokyo, Japan, 6,595 miles. No one understood these terrific distances better than the Naval Air Transport Service; therefore, as soon as possible they scheduled and maintained routine service from the United States to all areas, just as soon as the islands were conquered and the Navy Seabees could construct the air bases.

Thus in August 1944, when the Naval Air Transport Service was approached relative to carrying all of the shipments of whole blood from the United States to the Pacific theater, a schedule of 34 hours of actual flying time was projected from Oakland, Calif., to Guam in the Marianas where the advance base blood distribution center was to be. This schedule was always maintained. From Guam, the Army Transport Command did a fine piece of work in carrying into the Philippine Islands all of the whole blood required there throughout all of their campaigns. For the interisland transport, the Transport Air Group, a cooperative venture composed of Army, Navy, and Marine pilots and ground crews did outstanding work in flying the blood wherever needed, very often into combat areas and through bad weather. Interisland trips in the Philippine Islands were made by the 15th Army Air Force, and not infrequently the Army L5, a Cub type plane with single powerful engine, was used to fly into valleys and otherwise inaccessible areas. These planes carried blood and medical equipment in, and evacuated patients on the way out.

The Temperature Problem.—The second was the tropical climate, with temperatures rarely under 90° F. (32° C.) and often as high as 130° F. (54° C.) to 140° F. 60° C.)

It was necessary to design and test an expendable refrigerator (figure 1) which would maintain whole blood between 36° F. (4° C.) and 50° F. (10° C.) for at least 36 hours, at an average ambient temperature of 76° F. (22° C.).

a. The Requirements for Refrigeration: The requirements for necessary refrigeration were as follows:

(1) That the blood be maintained at a temperature not less than 36° F. (4° C.) nor greater than 50° F. (10° C.).

(2) That the refrigerated box be expendable, as light as possible, and capable of transporting about 16 pints of blood.

(3) That the blood be placed in removable racks to facilitate handling. In the design of the refrigerator, ice appeared to be the ideal refrigerant, because of its general availability, and since its use practically eliminates the risk of the blood temperature going below 36° F. (4° C.), a circumstance which might occur if dry ice were used. The latent heat of fusion of ice provides a moderately efficient heat reservoir but is was essential also to provide insulation of low density and thermal conductivity. A rapid survey of available portable refrigerators including a stainless steel vacuum jar was made, but none was found which met requirements. Several lightweight refrigerators were therefore designed and models constructed and tested. The preliminary experiments revealed that round blood trays peripheral to the ice container were the most satisfactory. Various construction and insulating materials were tried in a number of combinations. Plywood of varying thickness, pasteboard, aluminum, masonite, galvanized iron, and copper wire were tested as construction materials, and various insulating materials were investigated to determine the most efficient types. From the tests then the following design evolved: The bottles were placed in round galvanized iron metal trays through which a central galvanized iron ice cartridge passed. This unit was then placed in a double-walled box, the outer wall being made of plywood and the inner wall of pasteboard with lightweight insulation between them. To facilitate re-icing at advanced distribution centers, the ice cartridge was made removable.

b. Testing of Trial Model: The refrigerator was tested by loading it with 16 bottles of blood, and precooling it in a cold room to 36° F. (4° C.), which required 6 to 9 hours when refrigerator and blood were warm. The ice container was then packed tightly with chipped ice and placed in a room for tests at varying temperatures. The temperatures of: One, ambient air; two, the outside of a bottle on the bottom tier; three, the outside of a second bottle on the bottom tier; and four, the outside of a corner bottle on the top tier, were measured by thermocouples and a mixromax recorder. When the ambient temperature was 80° F. (27° C.), all temperatures of the surface of blood

bottles remained within the limits set (36° F. (4° C.) to 50° F. (10° C.)) for 50 hours, or 14 hours beyond the specified duration of 36 hours, including a safety factor of 5° C. The total weight for the finished model was 87 pounds, completely packed with sixteen 600-ml. bottles of blood.

The Preserving Solution.—The third was the fact that blood banks operating in the United States rarely had used blood over a total of 7 days of age and very often the top limit was 4 days; thus, a different anticoagulant preserving solution was necessary, for it was obvious that valuable days would be lost during processing, and transportation from the United States to the various Pacific stations.

As early as 1916 it was known that the addition of dextrose to a citrated blood would aid in the preservation of the erythrocytes as described by Rous and Turner. In the December of 1943 British Medical Journal, Loutit and Mollison stated that their citric acid, sodium citrate, and dextrose anticoagulant solution resulted in: One, improved preservation; two, the ability to autoclave the solution without caramelization occurring; and three, the sodium citrate in concentration was adequate to prevent clotting. Thus, this combination of the above constituents provided for the longest survival of the transfused red blood cell.

As a result of intensive studies of various diluting fluids, carried out by several groups of investigators working under the Committee of Medical Research of the Office of Scientific Research and Development, advisors in the National Research Council recommended a slightly modified Loutit-Mollison solution as providing for the longest survival of the cells in preserved blood.

4. *Standard Type of Equipment.*—Fourth, a standard type of equipment had to be set up for the entire program. The equipment for the blood bank was necessarily of the highest specification.

Preliminary Studies on Whole Blood Shipments.—Fifth, before starting on this program, a number of studies on older aged, refrigerated, and transported blood were necessary to finally assure those concerned with the safety of the project.

In addition to the above-mentioned considerations it was important that a few more questions be answered in a practical manner. They were namely, (*1*) the degree of cell break-down in actual shipments of blood with the resulting increases in plasma hemoglobin, plasma bilirubin, osmotic fragility, and also check cross-matchings and iso-agglutinin titers.

The Naval Medical Research Institute at Bethesda attacked the above problems, using blood in the previously described 600 cc. type bottle containing the A C D or Loutit-Mollison solution, for an anticoagulant. Blood samples used were of the following ages: (*a*) 10 samples under 4 days of age, as controls, (*b*) 8 samples 10 to 20 days of age, and (*c*) 35 samples 22 to 31 days of age. The bloods were drawn on the west coast and sent to Washington by air under refrigeration. Sixteen of the bloods were sent to Pearl Harbor and thence back to the United States to Washington, D. C. An analysis of the results showed that in none of the specimens did the plasma hemoglobin ever exceed 25 mgm/100 cc. In transfused patients, there was found to be mild hyperbilirubinemia which returned to normal within 24 hours. The effects in multiple transfusions were not cumulative and in only one very ill patient with a ruptured appendix and peritonitis did the bilirubin level rise as high as 3.5 mgm.100/cc. The norm for the osmotic fragility in fresh blood was 0.55 to 0.6 percent NaCl whereas with stored 21-day-old blood it was 0.70 to 0.80 percent NaCl.

All bloods were regrouped for checking the grouping processes, and no errors were encountered. The over-all iso-agglutinin titers ran as would be expected from a low of 1–32 to a high of 1–1,024 in the anti-A and anti-B agglutinins.

In an analysis of 575 different sera against known cell suspensions of groups A and B by Kettel it may be seen in that series that only 1 percent of anti-A agglutinins reached a titer of 1–1,024 and but 1.5 percent to 1–512, and 5 percent at 1–256. All the other 90 odd percent were below that with the peak of 40 percent at 1–64. The anti-B titers ran universally lower, with 1 percent at 1–512 and 2.5 percent at 1–256, with its peak at 1–16. Thus, as concerns the number of possible excessively high titers anti-A and anti-B agglutinins, the chance of serious agglutinin reaction is relatively low in type "O" whole blood obtained from the donor population at large.

It has been shown in recent years that indiscriminate use of universal donor blood does not

constitute as great a danger as was formerly believed. Riddell (5) reported that in France in the experience of Transfusion Sanguine D'Urgence in Paris about 6,000 universal donors per year were supplied without a fatality occurring as a result of transfusion.

Slight Chance of Serious Reaction.—Although, the chance is slight, serious reactions can and do occur from high titered group "O" universal donor blood as reported by Levine and Mabee (6) and Aubert, Boorman, and Dodd (7) who demonstrated the occurrence of intravascular agglutination and hemolysis in a significant percentage of cases following the transfusion of serum of group "O" into recipients belonging to group A.

THE BLOOD COLLECTION PROGRAM

In order to standardize the collecting of blood in the various centers all procedures were carefully set forth, and the greatest supervision was exercised over equipment and personnel in all of their exacting functions. It should be stressed that the success of the program was entirely dependent on careful bleeding, expert check typing, precooling of donor bottles, and immediate refrigeration of the blood. This was always done.

THE CONTROL OF THE WHOLE BLOOD PROGRAM IN THE UNITED STATES

This control was not especially difficult for it was merged with the plasma procurement program; thus, but for new centers to be opened on the west coast little more other than that previously discussed was needed. The centers which provided the whole blood for the Pacific Theater of Operation were San Francisco, Calif., in the first place on the donor list; Los Angeles, second; and in the following order of totals in contribution, Oakland, Calif.; Portland, Ore.; and San Diego, Calif.; those east coast centers which sent their whole blood at the cessation of European hostilities were New York, N. Y.; Brooklyn, N. Y.; Chicago, Ill.; Boston, Mass.; Philadelphia, Pa.; and Washington, D. C. (The eastern cities are not placed in order of their total donations.)

On signal from the blood distribution center at Guam to the West Coast Blood Bank Facility at San Francisco, that facility would then estimate the ability of all the bleeding centers to meet the over-all demand for blood after consulting with the technical director of the program in Washington, D. C. Thus, the load of distribution from all centers was adjusted. It is interesting to note that 80 percent of all the blood supplied to the Pacific was gathered from the west coast donor centers, for the east coast donor centers were primarily concerned with supplying blood to the European Theater of Operation up to the cessation of hostilities in that theater. Thus no small tribute is due to those centers who always met the demands of war no matter how severe they were, and very often they were very severe.

PACIFIC DISTRIBUTION

The facility at Guam in the Mariana Islands was officially known as the U. S. Naval Whole Blood Distribution Center No. 1 in contradistinction to calling it a blood bank, which implies blood collection and donor processing, for none was done at that center. The base at Guam was selected because of that island's strategic location as a central point for all future operations.

The first shipment of 5 cases of 80 pints of human whole blood arrived at Guam on 19 November 1944.

Figure 3 portrays the distribution areas much better than a written description could, and but for a few details further discussion is not necessary.

In the Philippine Islands the U. S. Army blood-bank facilities were located at Tacloban on Leyte Island where Capt. H. H. Thorpe (MC), A. U. S., handled the difficult over-all distribution to all the other Philippine Islands.

At the time of invasions, LSTH's were mounted with blood prior to proceeding to the target, and as required, a complete blood distribution team would be put ashore with its independent 150-cubic-foot refrigerator, a portable electric generator to supply current, an ice machine, and transportation facilities in the form of truck or jeep. The team was under the direction of an officer well-trained in the proper screening and handling of whole blood, and was composed of sufficient personnel to run the unit from a mechanical as well as a biological aspect. It was overstressed to all personnel handling blood in the Pacific Theater

that improperly cared for blood could easily cause fatal reactions.

FACTORS OF OPERATION

The discussion of type of equipment, preserving anticoagulant solution, and transportation has previously been dealt with; but factors of operation on Guam and in other areas are deserving of further discussion.

Guam was selected as the distribution point, because using that as a center, all future areas of operations up to and even including Japan itself were but some 1,600 miles away, or approximately 8 to 9 hours by air.

The distribution center was set up at Naval Air Base, Agana, Guam, and consisted of two Quonset huts, one of which housed the ice machine, a laboratory, an office, and the other a storage hut for the blood boxes, for in addition to the running supply an extra hundred empty boxes were maintained there in case of emergency. A covered elevated platform was built in front of the huts to keep the boxes out of the mud and to protect them from the weather and truck traffic while being unloaded from planes. Four 675-cubic-foot refrigerators were needed for the peak loads. Although, the activity started with but one refrigerator, it acquired additional units, one by one, as the demands increased, and a fifth was on order for construction when the war ended.

The center itself was situated contiguous with the air field and was but 100-odd yards from where the planes loaded and unloaded. Thus trucks were not necessary for loading and unloading the planes, and finger lifts could bring the boxes directly to the sheltered loading platform at the center.

After the blood had been stored in the reefer and allowed to settle for 12 hours, it was then checked for hemolysis and contamination by shining a microscope lamp through the plasma layer from which the red cells had settled. Even small degrees of hemolysis can thus be detected. Clots too can readily be visualized. Hemolysis was graded according to visual observation in terms of 1 plus, 2 plus, 3 plus, and 4 plus, with all bloods of a 2 plus classification and above discarded.

TABLE 1.—WHOLE BLOOD DISTRIBUTION IN PINTS BY MONTHS

ISLAND-BASED ACTIVITIES

Date	Campaign	Leyte	Guam	Saipan	Tinian	Iwo Jima	Okinawa	Pelileu	Japan
19 Nov.-24 Dec.	Leyte	4,256	253	128	.....	.....	.....	.....	.....
24 Dec.-31 Jan.	9 Jan. Luzon D-day	9,824	549	672	48	.....	.....	48	.....
1-28 Feb.	19 Feb. Iwo Jima D-day	8,480	240	2,064	112	.....	.....	48	.....
1-31 Mar.		10,304	1,364	1,712	16	.....	.....	32	.....
1-30 Apr.	1 Apr. Okinawa D-day	12,568	1,145	2,560	96	64	5,120	36	.....
1-31 May		15,748	1,810	2,880	480	144	12,922	.....	.....
1-30 June		13,144	1,171	960	160	160	7,148	.....	.....
1-31 July		8,256	1,068	584	88	72	848	.....	.....
1-31 Aug.		7,570	612	280	48	72	1,064	32	96
1-30 Sept.		2,936	414	376	64	48	444	.....	96

TABLE 1. (CONT.)—WHOLE BLOOD DISTRIBUTION IN PINTS BY MONTHS

Date	Campaign	Fleet Units	SHIPS Solace	Samaritan	Relief	Bountiful	Hope	Mercy	Comfort	LST 929	Miscellaneous
19 Nov.-24 Dec.	Leyte	288	.....	.....	.....	.....	.....	.....	.....	.....	
24 Dec.-31 Jan.	9 Jan. Luzon D-day	496	.....	.....	.....	.....	.....	.....	.....	.....	*Refuge*, 100.
1-28 Feb.	19 Feb. Iwo Jima D-day	784	1,216	96	.....	.....	.....	.....	.....	.....	
1-31 Mar.		1,936	960	880	1,280	.....	.....	.....	1,120	1,968	
1-30 Apr.	1 Apr. Okinawa D-day	176	560	1,920	.....	1,328	1,920	1,008	320	.....	
1-31 May		564	352	352	328	240	128	.....	.....	.....	
1-30 June		80	432	760	160	.....	.....	.....	.....	.....	*Rescue*, 192.
1-31 July		136	264	.....	112	.....	.....	.....	.....	.....	*Rescue*, 144.
1-31 Aug.		48	.....	.....	.....	.....	.....	.....	.....	.....	*Rescue*, 48; *Tranquillity*, 208.
1-30 Sept.		.....	.....	.....	.....	.....	.....	.....	.....	.....	*Benevolence*, 208.

Prior to reshipment of the blood the boxes are cooled in a reefer so that the warm box will not melt ice in the central container; thus the container, blood, and ice are in a condition of maximum refrigeration when leaving the reefer.

Statistics

Total bloods received at Guam..... 177,784 pints.
Total bloods shipped at Guam..... 171,564 pints.
Losses due to all cases, hemolysis, clotting, passed expiration date, and contamination. 6,217 pints or 3.4 percent for the entire program.

Logistics

Total weight, all shipments to Guam 966,700 lb. or 483.35 tons.
Total cubic feet all shipments from Oakland to Guam. 65,557 cubic feet.

In table 1 it is of interest to note the amounts of whole blood distributed to various of the larger bases and how the fluctuations coincide with the peak casualty loads. The Army in the Philippines estimated their whole blood needs to be 1½ pints per wounded individual. In the Pacific Ocean Area the estimates were calculated on a 1 pint per total casualty, i.e., killed, wounded, and missing, for a working hypothesis. Both methods were very closely correct in the over-all picture.

The figures in this table do not represent the entire whole blood expenditures and only the larger medical activities are listed. The Guam and Saipan totals represent hospital requirements for casualties and many of those cases had received blood transfusions prior to their hospitalization in the Marianas; thus, the patient load in the hospitals may have been approximately five times the figures listed at any time.

Another observation on fresh casualties returning from Iwo Jima to Guam revealed that of 3,460 stretcher cases, from 1 to 3 days removed from battle and time of injury, a total of 1,878 transfusions were required, or over 54 percent of those patients required transfusion. By thus carefully following the daily casualty figures and hospital admissions in the over-all Pacific Theater on tables such as these, we were able to continually estimate the whole blood requirements.

The amounts of blood sent to hospital ships likewise give a good indication of the magnificent

work that these vessels did in the treatment of as serious casualties as were seen in the entire war. It is to be noted that on the monthly issues of from 900 to 1,000 pints to some hospital ships, some of that blood was carried for "beach head" distribution, but in nearly all instances of figures below 900 pints, all of that blood was used by the individual ships themselves, in their respective monthly treatment of casualties.

The fleet needs were very difficult to estimate for units would either need no blood or a considerable quantity. It eventually resolved itself into a matter of those larger vessels, such as aircraft carriers and others in carrying 32 to 64 pints at all times during operations so that they would not have to bleed their crews if disaster occurred.

In calculating the amount of blood used for an entire operation such as Iwo Jima for example, the amount of blood used at hospitals on Guam and Saipan, etc., in the treatment of returning casualties was likewise counted, since all of those casualties were an actual part of the cost of battle. It was possible to obtain quite an accurate total because all of the hospitals were practically cleared of patients prior to a campaign, thus, all admissions thereafter which required a blood transfusion were counted as a cost of that action. Figures in table 1 represent the actual amounts of blood supplied to an individual base, but, for example, a hospital ship lying off Okinawa might have used up much of her monthly allocation of blood there, thus, the totals for the individual islands do not reflect the entire amount which was utilized for a campaign. See table 2 for campaign totals.

TABLE 2

Area of campaign, a specific unit:	*Total number of bloods required for the campaign*
Philippine Islands	93,086
Okinawa	44,802
Iwo Jima	16,224
To all hospital ships	18,068
Fleet units	4,508

REACTION REPORTS

It was realized that with the setting up and centralization of control of this project the data herein gathered would be of inestimable value to the medical profession. Having learned by experience that medical officers in combat areas could not fill out lengthy reports, it was decided that the simplest form of a report card should be used, and although this did not contain all the information to be desired, as much was requested as was thought to be practicable. Accordingly, a return addressed post card was used to gather reports from the over-all areas (figure 5).

A total of 21,296 of these cards was returned. Many were not completely filled out but there was adequate reporting to allow for an unusually large series of analyses. In calculating the reaction rates, every reported reaction was counted; there was no shading on this issue. It may be questioned that during the heat of battle a number of transfusion reactions occurred which were not observed. This fact is acknowledged, but it is likewise to be noted, as in table 1, that the greater majority of bloods went to establish base facilities, and that only during the first few "beach head days" of an operation would such hold true, for it did not require very long for hospital facilities, either ashore or afloat, to adapt themselves to a functioning routine within a relatively short period of time.

A number of considerations relative to the reaction rates will thus be considered; they are: Total over-all reaction rate, optimum age limits of blood transfused, reactions of type "O" administered blood to recipients with type "O" blood cells, blood groups as well as to types "A," "B," and "AB"; reaction rates according to various injuries; the *Rh* factor; allergic type reactions; reactions from different established activities and finally observations made upon older aged bloods, some of which were made available to natives on Guam who had no other means of furnishing blood for each other due to widespread anemia among all ages of the population. This resulted mainly from hookworm infestation, malnutrition, and tuberculosis. These and many other disease states were aggravated by the long period of Japanese occupation.

Total Reaction Rates.—Totals for entire program: Reported transfusions, 21,296; reported reactions, 676; reaction rate, 3.1 percent.

This series of blood transfusions constitutes one of the largest on record. DeGowin and Hardin *(8)* reported a 4.1 percent reaction rate on a series of 1,600 transfusions, with Hoxworth and Skinner *(9)* the same, a 4.1 percent reaction rate on 3,077 trans-

fusions. Wiener (*10*) points out that their low rates were undoubtedly due to: (1) careful typing, and (2) especial care with their transfusion equipment. It is to be remembered that all of the blood for the Pacific areas in the majority of instances was drawn and typed by experts, many of whom had 3 or 4 years' experience in blood bank work; that also the blood was never allowed to lose its refrigerated condition; and all sets were especially commercially prepared, used once and then expended, or at least not used a second time for blood transfusions. It is thus due to such simple expedients and care, as related above, which account for this low reaction rate. The major rules for safe and reaction-free blood transfusions are: 1. proper typing of blood, 2. constant and adequate refrigeration, and 3. sterile, pyrogen-free donor and recipient equipment, to which the greatest attention must always be paid.

Varying Ages of Transfused Blood.—In a discussion of the optimum age at which blood may be safely transfused it is emphasized that 21 days was and still is the top figure by choice, although blood of 28 days of age and older may be and has been given with safety. It is generally agreed that the rate of red cell deterioration over the 21-day period rises rapidly, but that at the 21-day period there still remains about 85 percent of the initial red blood cell efficiency; in other words, approximately 85 percent of the red cells, when transfused, will live to act as efficient oxygen carriers provided the blood has been stored at 4° to 10° C. in acid-citrate-dextrose solution. Blood over 21 days old may be safely transfused; however, it must be borne in mind that cell survival following transfusion declines rather sharply after the 21-day storage period. (Table 3 shows reaction rate of various aged bloods.)

TABLE 3

Age in days of "O" blood	Reported transfusions	Reported reactions	Reaction, percent (approximate)
4	46	3	6.0
5	130	7	5.2
6	188	4	2.0
7	296	20	6.6
8	421	17	4.0
9	508	23	4.6
10	618	27	4.5
11	561	29	5.1
12	680	25	3.6
13	387	18	4.5
14	417	19	4.7
15	525	20	4.0
16	549	20	4.0
17	466	23	5.0
18	417	14	3.5
19	321	12	4.0
20	358	22	6.0
21	257	14	5.5
22	191	6	3.0
23	98	2	2.0
24	104	3	3.0
25	53	3	6.0
26	65	2	3.0
27	38	3	8.0
28	29	3	10.3
29	32	2	6.0
30	34	2	6.0
31	6	1	.....
32	6	0	.....
33	5	0	.....
34	6	0	.....
35	7	1	.....
38	1	0	.....
41	1	0	.....
45	1	0	.....
46	5	2	.....
55	1	0	.....
61	1	0	.....
76	2	0	.....
Total:			
22 days or under	7,336	326	4.4
23 days or over	495	24	4.84
All ages	7,831	347	4.43

Iso-Agglutinin Effects on the Recipients of all the Blood Groups.—In this analysis data were not obtained from all of the 21,296 reports, for many cards did not have the recipient's type recorded. The conclusions drawn from table 4 have long been anticipated, and although no severe reactions were reported as due to unusually high titered blood, it is obvious from this series that varying titers of anti-A and anti-B in the type "O" donor blood were largely responsible for the increased reaction rate. To adjust this difficulty the addition of A and B polysaccharide type-specific substances, as done by Witebsky, (*11*) is to be recommended to neutralize the anti-A and anti-B agglutinins. The type "O" blood used in the Pacific was highly successful and in very few instances were cross-matchings carried out. This was a matter for the individual hospital and laboratory units to work out, but all concerned, when seriously rushed, did not cross-match; of course in cross-matching types other than "O" the recipient's serum and donor's cells side of the cross-match for type "O" blood

would be the only significant combination. With the addition of A and B group specific substances the necessity for cross-matching will be diminished, and especially so in the case of severe hemorrhagic emergency, where time is so valuable, this type "O" blood may be used. It should be stressed here, however, that no hospital or laboratory should ever consider cross-matching of blood as totally unnecessary, for the human error is ever present and must be carefully guarded against, and likewise at such a time the test for the *Rh* factor may also be carried out.

TABLE 4

Blood type of recipient	Reported transfusions	Reported reactions	Reaction rate
			Percent
O	2,851	109	3.8
A	2,056	119	5.8
B	549	37	6.7
AB	163	13	8.0

TABLE 5

Diagnosis	Reported transfusions	Reactions	Reaction rate
			Percent
Shrapnel wounds	250	5	2.0
Amputations	419	10	2.4
Fragment wounds	653	18	2.7
Burns	136	5	3.6
Gunshot wounds	1,385	52	3.7
Simple fractures	248	11	4.4
Compound fractures	368	20	5.4
Hookworm anemia	159	11	7.0

Reaction Rates in Various Injuries and Diseases.—Table 5 reveals factors which have long been considered as contributary to reactions, but generally data have been lacking in the size of the series to justify such conclusions; namely, that with more extensive and serious traumatic injuries, reactions are more prone to occur, and likewise with the severe anemias the same holds true. All the hookworm anemias treated by blood transfusion were under 3.0 million red blood cells, many were under 2.0 million, and a few under the count of 1.0 million red blood cells.

The Rh Factor and Its Effect on Reaction Rates.—It was well appreciated that many injured and sick recipients would be *Rh* negative and particularly where multiple transfusions were concerned, would receive type *Rh* positive blood with resulting degrees of sensitization. It is to be remembered, however, that during the war the situation was one of extreme emergency, both at the collecting centers in the United States where the *Rh* testing sera was not available in quantity, and also because the extra time consumed with such tests would have seriously hampered the volumes of whole blood needed. Likewise the recipients were practically all males who, even though sensitization was actually occurring, would require in most cases, weeks or more of time prior to attaining a high enough titer where serious reactions might occur. Erythroblastosis of course was never a factor. In other words it was a question of outright saving of lives by immediate replacement of blood lost from hemorrhage. Now, months after treatment, however, it should be stressed that particularly those recipient patients who received multiple transfusions should in the advent of future transfusions, be most carefully checked for the *Rh* factor reactions. Some recent tests made on recipients of multiple transfusions have shown that sensitization has occurred to some degree in a few patients.

Allergic Reactions.—In a separate group of 381 reactions out of 12,003 reported transfusions, there were 156 reactions or 41 percent of this series were reported on the cards as being allergic in type. Reports read, "urticaria," "hives," and "allergic type."

Since this series is so large it is evident that about half of all reactions in this series are due to an allergic type of response. This is quite an important factor since in the care of seriously ill patients one wishes to minimize the chance of reaction. To safeguard them against allergic type reaction the following should be done: (1) A complete allergy history should be taken from the patient and if possible the donor; (2) fasting donors should be used; and (3) an intradermal skin test

may be employed by injecting 0.1 cc. of the fasting donor's serum in the recipient.

As one pays more attention to this type of reaction he certainly will lower the reactions due to this rather elusive agent.

Reaction Rates in Different Medical Activities.—Table 6 illustrates the varied reaction rates in different hospital facilities using large quantities of blood, and it is obvious that there is considerable fluctuation here. This is definitely due to the degree with which the individual medical officer views a reaction. Some would even classify a reported, "chilly sensation," not accompanied or followed by a rise in temperature, as a reaction. Interpretation of the reactions was discussed many times in all Pacific areas to stress uniformity in reporting reactions, but in the final analysis all of the individual report cards were counted, if a reaction were recorded as having occurred.

Table 6 reveals a number of hospital activities picked at random to show the varying reaction rates.

TABLE 6

Activity	Reported transfusions	Reported reactions	Reactions, percent
44th General Hospital...	203	14	6.9
118th General Hospital..	912	23	2.5
126th General Hospital..	608	4	.6
133d General Hospital..	222	0	0
148th General Hospital..	3,093	102	3.3
204th General Hospital..	1,040	35	3.3
117th Station Hospital..	138	4	2.8
369th Station Hospital..	598	16	2.7
Fleet Hospital No. 111..	358	17	4.7
Fleet Hospital No. 115..	175	11	6.0
Base Hospital No. 18...	616	5	.8
U. S. S. *Solace*.....	1,097	21	2.0

Reactions in Blood Over 21 Days of Age.—The native Chamorros on Guam have been among the most loyal people to the United States since 1898, but they were all in a most pitiable state at the time of the arrival of United States forces atter the invasion of Guam in July 1945. Malnutrition, severe hookworm infestation, widespread tuberculosis in young and old, and the dysenteries, both amebic and bacillary, had taken, and were taking, a terrible toll of life; the maternal mortality likewise was extremely high due to pre- and postpartum hemorrhage, and a blood count as high as 3 million red cells was most unusual among the hospital admissions of all cases. It was not infrequent to see, particularly among infants, counts as low as 750,000 red cells and more often approximately 1,000,000 red blood cells.

The Civil Affairs Hospital then approached the blood distribution center on Guam and asked if it could spare any blood for the maintenance and function of their hospital, for iron and liver in all forms along with plasma and albumin had no effect in combatting or correcting the anemias. The blood distribution center could spare but little blood due to the needs of the casualties, but bloods over 21 days of age were made available rather than discarded. The success of this older blood was amazing, and even moderately hemolized blood, up to a visual classification of 2 plus to 3 plus, gave no reaction whatsoever. The results were most gratifying, for the response to recovery and without reaction, was immediate even with blood up to 40 days of age. The facts which were learned from this cooperative effort thus often enabled one to feel perfectly safe, during extremely heavy demands and casualties, to issue blood up to 28 days of age for use. If the 21-day dating period had been strictly adhered to, several thousands of pints of blood might have been lost due to the fact that the expiration date had been exceeded.

Thus, due to an emergency situation, a much greater number of patients benefited from the extra available whole blood. Not only was better medical care given to the Guamanians, but also once restored to health some 20,000 extra hands were made available to assist the armed forces in a more rapid conclusion of the war.

SUMMARY

1. The preservation, refrigeration, and distribution of human whole blood from the United States into the tropical areas and combat zones was one of the major advances of modern medicine in World War II.

2. In preparation for war, and during the early phases of combat, human dried plasma and albumin were made available to the United States forces in adequate amounts, but it was not long before the need for large amounts of whole blood became evident in both theaters of the war.

3. The first large shipments of whole blood from the United States donor centers started in August 1944 for the European Theater and in November 1944 for the Pacific Theater; and the period covered by this report extended from 19 November 1944 to 21 September 1945.

4. The problems of distance, tropical conditions, preserving solution, standard equipment, and practical studies on transported blood had to be solved prior to undertaking the Pacific distribution. Distances were overcome by granting all whole blood shipments a No. 1 air priority for all transportation. The refrigeration was maintained through the medium of a 5.9 cubic foot refrigerated box with water ice, and containing 16 pints of whole blood which would be maintained at a temperature from 8° to 10° C. for as long as 50 hours. A preservative anticoagulant solution known as the acid-citrate-dextrose or (Loutit-Mollison solution) enabled blood to be safely stored and utilized up to 21 days from the date of bleeding and even longer in the case of emergencies. Standard donor and recipient equipment was set up with the blood bottle being a vacuum type 600 m. bottle containing 480 cc. of blood and 120 cc. of anticoagulant solution. Finally, studies on transported blood of ages from 4 to 31 days gave early assurance of the safety and practicability of this projected distribution and use.

5. The procurement for the blood collection program was made the responsibility of the American Red Cross with bleeding and processing being placed under the technical supervision of the Army and Navy. The program for the European Theater of Operation was under Army control and that of the Pacific Theater by the Navy. New west coast centers were opened to meet the Pacific demands but following the cessation of hostilities in Europe the east coast also contributed to the Pacific Theater.

6. In the operation of the program, all the blood was flown by the Naval Air Transport Service from Oakland, Calif., to Honolulu. There it was re-iced and then flown on to Guam where the U. S. Naval Whole Blood Distribution Center No. 1 stored all blood in large refrigerators for a minimum of 12 hours, and visually examined all bottles for hemolysis, contamination and clots, discarding all unsuitable units. Visual inspection proved entirely satisfactory for the entire program.

7. Statistical data revealed 177,784 pints of whole blood were received at Guam from the United States, and a total of 171,564 pints were reshipped, accounting for a 3.4 percent over-all loss at the distribution center at Guam. The total weight of all shipments to Guam was 966,700 pounds or 483.35 tons, and required a total of 65,557 cubic feet of plane space for the shipments.

8. Distribution to various areas showed that the Philippine Island campaigns required 93,086 pints, Okinawa 44,802 pints, Iwo Jima 18,068, fleet units 4,508 and all hospital ships 18,068 pints. Table 1 illustrates the individual shipments and allows for a more vivid impression as to the pressure of casualties in the progressive campaigns.

9. Reaction reports were gathered on a small postal card type of report form. A total of 21,296 reports were returned and of these there were 676 reactions with a resulting reaction rate of 3.1 percent.

10. In types other than "O," the reaction rates were above those of the type O recipients, thus tending weight to the desirability of adding type A and B groups specific substance in order to neutralize the iso-agglutinins.

11. The reaction rates were graded as to various types of the injury and the rates were higher as the degree of tissue injury increased.

References

1. Whitby, L. E. H.: British Army blood transfusion service. J. A. M. A. 124: 421–424, Feb. 12, 1944.
2. Rous, P., and Turner, J. R.: Preservation of living red blood cells in vitro. J. Exper. Med. 23: 219–237 (Part I. Methods of preservation); 239–248 (Part II. Transfusion of kept cells). Feb. 1916.
3. Loutit, J. F., and Mollison, P. L.: Advantages of disodium-citrate-glucose mixture as blood preservative. Brit. M. J. 2: 744–745, Dec. 11, 1943.
4. Kettel, J., Levin and Munksgaard: Undersgelser over Kuldehaemagglutininer i Menneskeserum. Copenhagen, 1930.
5. Riddell, V. H.: Blood Transfusion. Oxford University Press, London 1939. p. 49.
6. Levine, P., and Mabee, J.: Dangerous universal donor detected by direct matching of bloods. J. Immunology 8: 425–431, Nov. 1923.

7. Aubert, E. F., Boorman, K. E., Dodd, B. E., and Loutit, J. F.: Universal donor with high titre iso-agglutinins; effect of anti-iso-agglutinins on recipients of group A. Brit. M. J. 1: 659–664, May 30, 1942.

8. DeGowin, E. L., and Hardin, R. C.: Reactions from transfusion of preserved blood; experience with 1,600 transfusions. Brit. M. J. 2: 1–5, July 6, 1940.

9. Hoxworth, P. and Skinner, C.,: Improvement in blood transfusion service; establishment and operation of blood transfusion service. Arch. Surg. 42:480—497, March 1941.

10. Wiener, A. S.: Blood Groups and Transfusion. 3d edition. Charles C. Thomas, Springfield, Ill., 1943.

11. Witebsky, E., and Klendshoj, N. C.: Blood group specific substances and blood transfusions. Science 94: 256–257, Sept. 12, 1941.

12. Witebsky, E., Klendshoj, N. C., and Swanson, P.: Preparation and transfusion of safe universal blood. J. A. M. A. 116: 2654—2656, June 14, 1941.

Acknowledgment

This material is largely based upon the following publications and acknowledgment is hereby made to:

Bureau of Medicine and Surgery (Preventive Medicine Division). *Notes on Waste Disposal.* January 1945; *Notes on Water Supply Ashore.* January 1945.

U. S. Marine Corps. PHIB—21, *Amphibious Operations—Medical Service.* 1947.

U. S. Naval Medical Research Unit #2. *Basic Data for Military Usage of DDT, Repellents and Other Chemicals for Insect Control.* March 1945. *Basic Data and Plan of Operation for the Dispersal of DDT by Naval Aircraft.* March 1945. *Standard Procedures for Chemical Methods of Insect Control During Assault Phases of Military Operations.* March 1945.

U. S. Naval Medical Bulletin Reprints from the following articles: The Distribution and Use of Human Whole Blood In The Pacific War. Working Rules In The Field.

War Department Technical Bulletin. *Notes on Care of Battle Casualties.* March 1945.

INDEX

INDEX—*Continued*

INDEX—*Continued*

INDEX—*Continued*

INDEX—*Continued*

INDEX—*Continued*